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THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE V. VOL. VIII.

No. I.—JANUARY, 1911.

ORIGINAL ARTICLES.

I.—The Gulf of Suez.[1]

By John Ball, Ph.D., D.Sc., F.G.S. of the Geological Survey of Egypt.

In a previous paper published in this Magazine,[2] I gave reasons for the belief that neither the Gulf of Suez nor the valley of the Nile owes its origin to trough-faulting, as was at that time generally supposed. The skeleton of the argument was as follows:—

1. Extensive faulting at the faces of the scarps of the Nile Valley and Gulf of Suez cannot be held to be evidence of trough-faulting, since the same can be observed along the scarps of the Wadi Araba, the structure of whose floor shows it to be an eroded anticline, and the faults along its scarp-faces to be merely huge landslips.

2. The faulting observable immediately along the coast of the Gulf of Suez is of an exactly similar nature to that above mentioned, and along part at least of the gulf the strata dip away from the sea on the opposite coasts, leading to the inference that the Gulf of Suez is, like the Wadi Araba, an eroded anticline.

3. If it be granted that the Gulf of Suez is not a trough-fault, the argument against the Nile Valley being a trough-fault is strengthened, the support of parallelism being removed.

A discussion of the paper with various fellow-workers has indicated entire agreement as to the Nile Valley having been cut out by erosion, but at the same time has shown a tendency to suspension of judgment regarding the origin of the Gulf of Suez. I have therefore searched diligently for further facts which might throw light on the origin of the gulf. Since writing my last paper I have spent a season surveying in the neighbourhood of Gebel Zeit. Though the work was confined, by other considerations than geology, to a small part of the Egyptian side of the gulf, and has in consequence not furnished much additional evidence, I may say that such observations as I was able to make were all to my mind corroborative of the conclusion to which I had already been driven, viz. that the Gulf of Suez owed its origin to erosion and not to trough-faulting; for example, I remarked that the Nubian Sandstones on the north-east flank of Gebel Zeit dip strongly away from the gulf, which one would not expect them to do if the gulf had been faulted down. Since more extended field

[1] Communicated by permission of the Director-General, Survey Department, Egypt.

[2] Geol. Mag., Dec. V, Vol. VII, pp. 71–6, 1910.

observations were not possible at present, it occurred to me that something in the way of evidence might be gathered from a careful study of soundings in the gulf. As one of the world's great highways of commerce, the Gulf of Suez has been thoroughly sounded by the British Admiralty, and the Gulf of Akaba and the Red Sea have likewise been subjected to sounding observations, though of a less degree of closeness. I therefore took the large-scale Admiralty chart of the Gulf of Suez,[1] and, using the soundings as a guide, drew in the contours of the sea-bottom at 10 fathom intervals. I also examined the smaller-scale chart[2] on which the Gulf of Akaba and the north part of the Red Sea are shown, and compared the soundings in these parts with those of the Gulf of Suez. The results furnish, I think, a strong argument for the erosive origin of the Gulf of Suez.[3]

The first striking conclusion from an examination of the charts is the extreme shallowness of the Gulf of Suez as compared with the Gulf of Akaba and the Red Sea. The deepest sounding in the Gulf of Suez is a solitary one of 63 fathoms south-east of the Island of Jubal, and even this is a very local deepening,[4] for there is no sounding indicating a depth of over 50 fathoms at any other point in the gulf; while the Gulf of Akaba is a deep trough with a maximum depth of over 700 fathoms, and the Red Sea, even close south of the Gulf of Suez, goes down to over 600 fathoms. The remarkable contrast between the Gulfs of Suez and Akaba in regard to depth is shown in the transverse section across the two gulfs, drawn to a natural scale in Fig. 1. A subsidence of only 100 metres, which is nothing more than can be accounted for by secular oscillation of the earth's crust, such as is known to be going on in many parts of the world, would leave the Gulf of Suez high and dry, while the Gulf of Akaba and the Red Sea would be but little altered in outline, and would remain very deep seas. Further, it will be seen from the longitudinal sections, shown in Fig. 2, that while in the case of the Gulf of Suez there is a gradual fall to the greatest depth at the mouth, and a final huge drop to the Red Sea, in the case of the Gulf of Akaba we have a trough with its greatest depth near the centre, and a transverse 'horst' separating that trough from the Red Sea. Can anyone conclude that the two gulfs have a like origin? To explain so deep a trough as the Gulf of Akaba, devoid of outlet for over a kilometre of its depth, a local subsidence may well be invoked, more especially as it forms the geographical continuation of the Jordan Valley, as to whose origin in a trough subsidence there can, I suppose, be no doubt. But the Gulf of Suez is an entirely different matter. When we realize that the Gulf of Suez is neither parallel to, nor a prolongation

[1] Admiralty Chart No. 757, revised to 1908.

[2] Red Sea Sheet No. 1, Admiralty Chart No. 8*a*, revised to 1897.

[3] It is remarkable that these same charts appeared to Mr. Barron and Dr. Hume to support the idea of a trough-fault origin for the gulf, which is just what I consider the charts disprove. See *Topography and Geology of the Eastern Desert of Egypt, Central Portion*, Cairo, 1902, p. 213. My colleagues would, I think, have been driven to an opposite conclusion had they drawn in the contours of the entire gulf, or constructed a section across it to a natural scale.

[4] Such local deepenings occur in many river valleys, usually in consequence of a waterfall; an example occurs in the Nile Valley below the First Cataract.

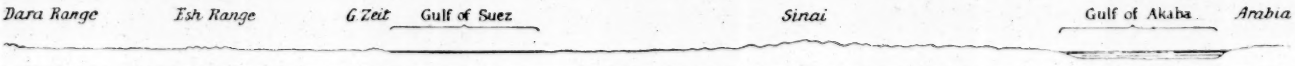


FIG. 1. Transverse section from the watershed range of the Eastern Desert of Egypt, across the Gulf of Suez, Sinai, and the Gulf of Akaba to the Arabian coast. Plotted to a natural scale. The horizontal line forming the base of the diagram is 2 miles below sea-level.

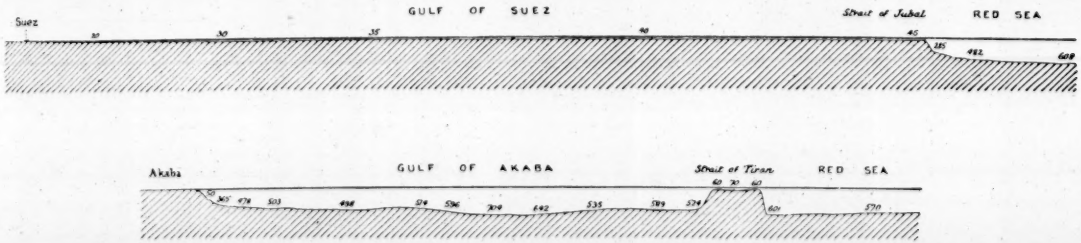


FIG. 2. Longitudinal sections of the Gulfs of Suez and Akaba, drawn to the same scale for comparison. The vertical scale is ten times the horizontal one. The figures give the depth in fathoms from the Admiralty soundings.

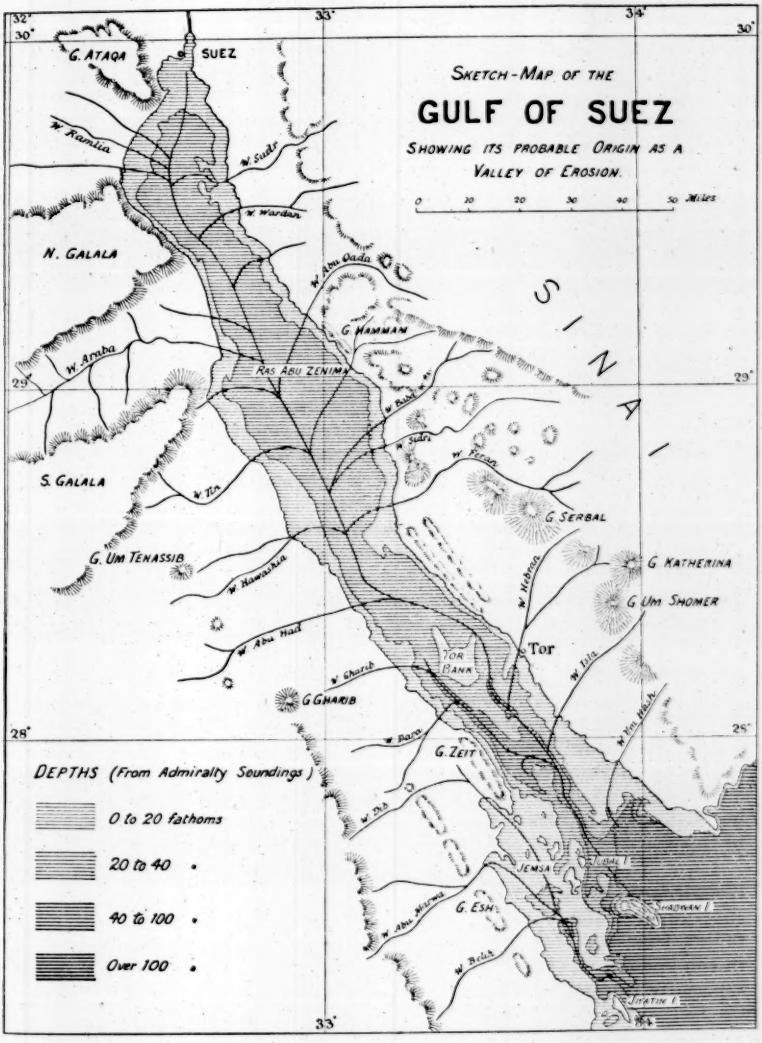
of, any known area of trough-subsidence other than the Red Sea, from which sea the contrast in width and depth is so remarkable as to suggest genetic independence rather than community of origin; when we contrast the shallowness of the Gulf of Suez with the more than tenfold greater depth of the Gulf of Akaba; above all, when we remember that secular movements are known to have gone on comparatively recently in the district,[1] and that such a movement downwards of less than 100 metres is all that is necessary to account for the submergence of dry land to form the existing gulf; we must feel hesitation at pronouncing the Gulf of Suez to be a trough-subsidence.

But that is not all. Let us consider the contours of the floor of the Gulf of Suez, shown in the sketch-map on p. 5. This map is reduced from a much larger one which I made, and the smallness of the scale has rendered it impossible to show the contours at 10 fathom intervals; I have therefore shown only the 20, 40, and 100 fathom lines, which indicate the shape of the bottom of the gulf sufficiently well for the purpose of discussion. The shape of the floor of the gulf is exactly that of a great flat-bottomed valley such as the Wadi Araba or the Wadi Qena. Even where the slope downwards from the shore towards the centre of the gulf is steepest, as for instance near Gebel Zeit, the 20 fathom contour is seldom within half a mile of the coast, which only corresponds to a slope of about 1 in 40; and as the slope of the adjacent land is greater than this, there is no sudden deepening, such as might indicate a trough-fault, but rather a general continuity of slope from hill-top to sea-bottom.[2] Moreover, the fall of the sea-bottom lengthwise is practically continuous from Suez to the Red Sea.[3] Another suggestive feature is that there are indentations of the contours of the floor of the gulf opposite the mouths of many of the wadies draining into it; these indentations are not very evident on the small-scale map, owing to the fewness of the contours which can be shown; but they are more marked on the larger scale, where the 10 and 30 fathom lines are drawn in. It is extremely unlikely that the bottom of the gulf has been eroded in this curious manner by deep currents; the tendency of the sea will rather have been in the direction of the silting-up of any pre-existing deep hollows. What is the only other deduction? Must we not conclude that the Gulf of Suez is a submerged valley of erosion, by which the wadies now draining from Egypt and Sinai to the gulf formerly emptied their contents by trunk-channels into the Red Sea near what is now the Island of Shadwan? I have drawn the main lines of this suggested former drainage system in the sketch-map, from which I think the connexion between the existing wadies and the shape of the floor of the gulf will be evident.

[1] Evidence of raised beaches. See Barron & Hume's *Eastern Desert*, p. 139.

[2] Recent coral reefs have in parts given rise to small steps in the slope near the present water-line, but it will be perceived that these have nothing to do with the argument.

[3] The only break in the continuous slope down the gulf as shown by 10 fathom contours is a slight rise of a few fathoms a little north of latitude 28. It is probable that the soundings may have missed the very deepest parts here, or that silting or coral-growth has filled up the hollows to the thickness of a few fathoms.


SKETCH-MAP OF THE
GULF OF SUEZ
SHOWING ITS PROBABLE ORIGIN AS A VALLEY OF EROSION.
0 10 20 30 40 50 Miles
G. ATAQA
SUEZ
W. Ramlia
W. Sudr
W. Wardan
N. GALALA
W. Abu Gada
G. HAMMAM
W. Amba
RAS ABU ZENIMA
W. Baba
W. Sudr
W. Feran
S. GALALA
W. Tih
G. SERBAL
G. UM TENASSIB
W. Hawashia
W. Hebran
G. KATHERINA
G. UM SHOMER
W. Abu Had
TOR BANK
Tor
W. Gharib
W. Iala
G. GHARIB
W. Baras
G. ZEIT
W. Dab
JEMSA
G. ESH
W. Abu Mirawa
W. Bedia
SINAI
DEPTHS (From Admiralty Soundings)
0 to 20 fathoms
20 to 40 "
40 to 100 "
Over 100 "

In his recent paper dealing with the Nile Valley[1] my friend and colleague Dr. Hume, while agreeing entirely with me in the erosive origin of that valley, has mentioned two considerations which cause him to hesitate about accepting a similar origin for the Gulf of Suez. These are, firstly, the distribution of the Miocene beds, especially their absence from the Wadi Araba, and secondly, a difficulty in conceiving of erosion cutting through the dome or anticline which existed across the gulf, unless aided by fracture. These difficulties are easily explained.[2] As regards the distribution of the Miocene, much has yet to be done before a true picture of it is obtained. Where, as usually happens, the Miocene beds overlie older limestones, the limits are very difficult to trace in the field, the fossils, which are often extremely scarce, being the only guide. But from Mr. Barron's maps of Western Sinai it is apparent that the Miocene beds which cap the hill-ranges of the Sinai coast of the gulf dip inland, and thus we must infer that the deposition of the Miocene limestones antedated the folding which gave rise to the dome or anticline. Now since there is every reason to believe that the erosion of the Wadi Araba, like that of the gulf, occurred after the folding, the absence of Miocene beds from it is exactly what the erosion hypothesis requires for its support. Turning next to the conception of erosion cutting through the dome without fracture, I would remark that fracture at the top of the dome or anticline is quite possible; in fact, the weakening of the beds at the top of the arch under tension is probably the key to why the drainage-line assumed its actual position. I am not, however, now concerned with the causes which determined the position of the drainage-lines along which erosion went on, my point being only to show that erosion, and not trough-faulting, has removed the beds which formerly stretched across the gulf. And fracture is not trough-faulting. The fracture at the top of an anticline is brought about in an entirely different manner from a trough-fault, the one being due to tension by bending of the beds under tangential pressure, the other to shearing by radial subsidence. Moreover, we cannot get away from the fact that the Wadi Araba has actually cut through the same dome or anticline, its drainage-line, in fact, going inwards from the edge to near the centre of the dome; and what has actually happened in the case of the Wadi Araba is surely not inconceivable, but rather likely, in the case of the valley which gave rise to the Gulf of Suez.

I would remark that in arguing that the Gulf of Suez is not due to trough-faulting, and that the faults which bound it along the edge of the North Galala plateau are merely huge landslips and not true faults, I am very far from stating that no true faults are to be found in the lands bordering the gulf. True faults do occur on both sides, especially in Sinai, and possibly they may exist even in the gulf itself;

[1] Geol. Mag., Dec. V, Vol. VII, p. 388, 1910.

[2] I regret that owing to our separation for a long period I did not have the opportunity of explaining these difficulties to Dr. Hume before he published his paper. To English readers it will appear strange, but when one of two workers is in Cairo and the other is in the desert, they are frequently much further apart as regards time of communication than if one were in England and the other in Khartoum.

but my point is that they have no direct genetic connexion with the Gulf of Suez as we now know it, having taken place at a prior epoch to that of the erosion and submergence of the gulf. The rift-valleys of Eastern Sinai, observed by Dr. Hume,[1] are all parallel to the Gulf of Akaba, which is admittedly a trough-subsidence, and therefore show a true relationship with that gulf. But no undoubted trough-fault has ever been observed parallel to the Gulf of Suez, and there is no evidence for the existence of a second system of rifts inclined at a considerable angle to those of the great Dead Sea system, except the Red Sea itself. In his exploration of Western Sinai Mr. Barron[2] regarded only one line of valleys as safely attributable to 'rift', and the chief factor on which he based his judgment was parallelism with the Gulf of Suez. But to use this as any support in regarding the Gulf of Suez itself as a trough would be to argue in a circle.

The view of an erosive origin for the Gulf of Suez is, I think, now supported by strong evidence. As to its being an anticline, the evidence is but little less conclusive. The strata of the Galala mountains on the one side and those of Gebel Hammam on the other dip away from the gulf, so that in the north at least the gulf possesses an anticlinal structure. In the south part we have at present less complete data, and it is quite likely that the anticlinal structure there may be less simple and less pronounced than it appears to be in the north. But such observations as have been made are all in the direction of a general similarity of structure right down the gulf. Thus the beds forming the long coast-ranges north of Tor all dip away from the gulf, exactly as do those of Gebel Hammam, and the Nubian sandstones at the north end of Gebel Zeit likewise dip inland; while such scanty information as we possess from the islands near the Strait of Jubal all tend to indicate that an anticlinal structure is present there. The numerous borings now being made by prospecting companies on the islands will, we may hope, soon lead to more complete knowledge of the structure and nature of the rocks composing them.

It is interesting to see how easily we may trace the later geological history of North-Eastern Egypt on the view of the erosive origin of the Nile Valley and Gulf of Suez, together with those secular oscillations of the earth's crust in the district of which we have equally strong evidence in the numerous observations of Beyrich, T. Fuchs, Schweinfurth, Hull, and others. Any attempt at the reconstruction of the geological history of this part of Egypt must take account of the following facts,[3] in addition to those which I have brought forward to prove the erosive origin of the Nile Valley and the Gulf of Suez:—

1. The great depth of the bed-rock channel of the Nile in Lower Egypt, as proved by numerous trial borings; these borings all show a great thickness of sands and gravels to intervene between the present bed of the Nile and the bed-rock of its channel.

[1] "The Rift Valleys of Eastern Sinai": International Geological Congress, Paris, 1900.

[2] *Western Sinai*, p. 180.

[3] Most of these observed facts will be found summarized in Suess' *Face of the Earth*, English translation, vol. i, p. 380, 1904.

2. The occurrence of Pholas borings, discovered by Professor Schweinfurth, in the slopes of the Mokattam Hills, near Cairo, at an altitude of about 60 metres above the present sea-level.

3. The occurrence of sands with an Erythræan fauna of Pliocene age, near the pyramids of Giza, 64 metres above the present sea-level, as shown by Beyrich and T. Fuchs.

4. The mingling of Mediterranean and Erythræan faunas in the shell-beds near Suez, as proved by the researches of Issel.

5. The occurrence of alluvial deposits with Nile shells on the Isthmus of Suez.

6. The traces of an ancient sea-level, 60 metres above the present one, near Suez, observed by Professor Hull.

7. The raised beaches of Pleistocene age on the shores of the Gulf of Suez, some of which are 158 metres above the present sea-level, according to Barron and Hume's measurements.

I shall show that all these various facts can be explained easily and naturally as consequences of erosion and secular oscillation of the earth's crust, without invoking the aid of any such catastrophic changes as the letting-down of large tracts by trough-faults.

Accepting the erosive origin of the Gulf of Suez as sufficiently indicated by the considerations I have already given, we may first inquire into the probable antiquity of the valley whose submergence gave rise to the gulf. It cannot be older than the Miocene, for Miocene beds cap hills on both coasts, and appear to have undergone the folding which I have mentioned as evidence of the anticlinal structure of the gulf. The earliest date possible for the commencement of the erosion must be the latter part of the Miocene period, when a great rise of the crust took place in North-East Africa, with folding and faulting. This folding and faulting, far from producing the Gulf of Suez by subsidence, raised the land-surface over its present site. The folding probably had some part in determining the course of the drainage-lines, by weakening of the folded strata; but the actual valley, whose submergence at a later date was to give rise to the gulf, was yet to be excavated by river-action. The erosion of the valley may well have gone on during the latter part of the period of elevation, as well as after it. The drainage down what is now the gulf would continually cut backwards (i.e. northwards, towards what is now the isthmus), gradually lowering the land-surface; but it is clear that so long as the gulf was a river-valley, the Isthmus of Suez must have been relatively high land. The length of the gulf from north to south is roughly 300 kilometres. Assuming that when the valley had cut itself back as far as Suez, it had an average slope of 1 in 5,000 (which is about twice as steep as the slope of the Nile between Cairo and Aswan), the land at Suez must have been at least 60 metres above sea so long as the gulf remained unsubmerged.

Now while the Gulf of Suez was thus being eroded as a river-valley, the Nile would be cutting its channel. The amounts of erosion evidenced in the Nile Valley and in the gulf are of the same order of magnitude, and the two valleys were most likely approximately contemporaneous in origin. And if the rise of land to 60 metres or more above its present level was general over the

northern part of Egypt, as is most likely, the Nile must have eroded its channel 60 metres or more below its present level in order to reach the sea; we have thus a simple explanation why the bed-rock channel of the Nile in Lower Egypt is so deep.

A great part of the erosion of the Nile Valley, and a still greater part of that of the Gulf of Suez, must have been accomplished between the Miocene and Pliocene epochs, when the land was at its maximum elevation. It is, indeed, likely that there has been practically no erosion of the bed-rock main channel of the Nile in the neighbourhood of Cairo, nor of the central line of the Gulf of Suez, since Pliocene times; and this not because of any cessation of the action of erosive forces in the district generally, but merely because these forces have been unable to exert themselves in these particular places; for the bed-rock channel of the Nile near Cairo has never since that time been above sea-level, and the Gulf of Suez has been continually an arm of the sea. Erosion was, however, going on with great vigour throughout the Pliocene and Pleistocene ages in all the tracts which remained unsubmerged. In the case of the Nile Valley the river continually cut backwards higher up its course, and the lateral drainages to it were actively eroding their channels, while there were doubtless migrations of the stream from side to side, tending to the continual broadening of its valley, in which river erosion was aided by weathering and landslips at the faces of the confining scarps. In the case of the Gulf of Suez the lateral drainages only have been active in erosion since the submergence of the trunk channel, but the vast extent to which this action has gone on is attested by the size of the Wadi Araba and the breadth of the sloping plains, covered with sand and gravel, which stretch in most places between the hills and the shores of the gulf.

In Pliocene and early Pleistocene times a subsidence of the land took place, submerging the lower part of the Nile Valley and the whole Isthmus and Gulf of Suez. The Pliocene sea entered the Nile Valley, deposited the Clypeaster sands near the pyramids, and gave rise to the Pholas borings in the face of the Mokattam Hills. The northern parts of the Nile Valley being submerged, the river would have its velocity checked by entering the sea at an earlier point of its course than formerly, and would thus be forced to deposit the sands and gravels which now overlie the bed-rock in the lower reaches of its channel. The sinking of the land to a depth of over 60 metres, which is necessary to account for the Clypeaster sands, the Pholas borings, and the old shore-line near Suez, must have submerged the Isthmus of Suez, and brought about that connexion between the Mediterranean and Red Seas which is evidenced by the mingling of the two faunas. The same sinking accounts for the raised beaches found along the shores of the gulf; to explain the higher beach, 158 metres above present sea-level, we have only to assume, what is indeed most likely, that the downward movement varied in amplitude in different parts, and reached its maximum amount in the district where this higher beach is found.

In the later Pleistocene period subsidence ceased, and elevation of the land set in. The Isthmus of Suez again became dry, and the two

seas were again separated as we find them to-day. The Nile mouth gradually progressed northwards as the land rose, the river cutting its present channel in the sands which it had itself previously deposited; and when the Isthmus of Suez was just about to emerge from the sea, a part of the river may well have discharged itself eastwards towards what was then the junction of the two seas, thus accounting for the alluvial deposits and Nile shells which occur on the isthmus.

There is some evidence that the upward movement of land in North-Eastern Egypt which went on in later Pleistocene times has now ceased, and given place to a slow sinking. Lyell[1] mentions the positions of tombs near Alexandria and the ruins of towns half submerged in Lake Menzala as evidence of this, and lately Mr. Villiers Stuart[2] has observed that certain areas of the northern delta, which carried a dense population in Roman times, are now uninhabited and only a few centimetres above sea-level.

I venture to think that the outline which I have given above of the later geological history of the Gulf of Suez explains, in a perfectly natural manner, all the facts of observation which it has hitherto been sought to explain on the trough-fault theory, and with less straining of probabilities. Our knowledge of the detailed structure of the gulf is far from being of that completeness which is desirable in a district which may possibly become one of the great oilfields of the world; but a working hypothesis of some sort as to the origin of the gulf is desirable, and I urge that erosion and secular oscillation is a far better working hypothesis, in the light of presently known facts, than local subsidence by trough-faulting.

II.—Observations on some Basic Dykes and their Bearing on certain Problems of Rock Genesis.

By F. P. Mennell, F.G.S.

(PLATES I AND II.)

IT is a common feature of the dolerite dykes in Rhodesia, especially where they penetrate the great granite masses of the country, that they show, even in hand-specimens, the presence of quartz. Usually this quartz occurs in good-sized corroded fragments which are quite obviously xenoliths derived from the surrounding rocks. Of this a fine example is to be seen close to Bulawayo Railway Station, where a small dyke is at one point so full of quartz fragments, up to several inches across, as to resemble a conglomerate more than an igneous rock. Other parts of this same dyke and many other basic dykes throughout the country contain quartz, either in separate granules or in the form of micropegmatite, whose origin is not so clear. It is with a view to elucidating this point that the present notes have been put together. They deal entirely with two intrusions cutting the great Matopo granite mass. The relative ages of the dykes and the granite cannot be given in precise terms, as the data

[1] *Principles of Geology*, 10th ed., vol. i, p. 438, 1867.
[2] *Cairo Scientific Journal*, 1909, p. 230.

1

[1737.] Fine-grained Dolerite, Antelope Road. × 20 diam.

2

[1738.] Granite xenolith, Antelope Road. ×20 diam.

3

[1701.] Modified Dolerite, with xenocrysts. Kahlele's, Matopos. × 20 diam.

Basic Dykes, Rhodesia.

are much too imperfect. The granite is presumably of Archæan age, and the dykes may be as late as Jurassic, though they may be older. That there was, however, a very great interval of time between the consolidation of the granite and the intrusion of the dykes is beyond dispute. We are certainly not dealing with products of related magmas or of the same general period.

Antelope Road Intrusion. This small intrusion of dolerite is situated about 100 yards east of the road, some 3 miles from the Matopo Hotel. It is a rather lenticular mass with straggly offshoots, and is fine-grained throughout, being markedly chilled at its junction with the granite, which is well exposed in a stream bed and on its banks. At the contact the granite has its felspars reddened and its quartz assumes a particularly glassy aspect, while the dolerite encloses numerous xenoliths of the granite a foot or so in diameter. In spite of chilling it has succeeded in insinuating itself among the constituents of the xenoliths to a most remarkable extent, so much so that in extreme cases almost every individual quartz and felspar grain is isolated from its neighbours by dark strings of basic material.

Microscopic Features. The dolerite is a granular medium- to fine-grained type without any features calling for special remark. One slide shows its junction with a granite xenolith [1737]. Pl. I, Fig. 1 gives a good idea of its appearance, and it need only be noted that much of the augite is uralitized. The edge of the granite xenolith is illustrated in Fig. 2. As will be seen, the fine-grained dolerite forms a kind of ground-mass in which the quartz and felspar of the granite are embedded like phenocrysts: the corrosion of the quartz and the incipient disintegration of the felspar are well shown. [1738] is cut from the central part of the same xenolith, several inches from the edge. Its interpenetration by the basic material is as conspicuous as near the margin. The matrix is of very fine-grained dolerite, with its ferro-magnesian constituent represented by pale-greenish hornblende and the iron-ore converted into leucoxene. Through this are distributed numerous xenocrysts of much corroded quartz, usually surrounded by a rim of fine-grained material, and others of felspar. The last are very cloudy in appearance, so much so as to be almost opaque, but the twin striations are not entirely obscured.

[1735.] This represents the main mass of granite within a few inches of the contact. It shows reddish altered-looking felspars, very glassy quartz, and strings of dark greyish-green material, which at once suggests the neighbouring fine-grained dolerite, intercalated among the quartz and felspar grains. Under the microscope the whole presents the appearance of incipient melting. The felspars are cloudy and altered-looking, but the twin striations are often tolerably well preserved, and the grains which show them can frequently be identified as the usual oligoclase of the Matopo granite, with straight, or nearly straight, extinction for both sets of twin lamellæ. Others, again, can be identified with considerable confidence as microcline, though the cross-hatching is only occasionally recognizable. The quartz is remarkably free from inclusions. Where, however, doleritic material is present, it is frequently much corroded and has minute needles of a mineral which is probably hornblende penetrating its

edges. The doleritic material is composed of the usual lath-shaped felspars, but, as in the previous case, the ferromagnesian mineral is now represented by hornblende. Between the quartz and felspar grains there is always a reaction rim, usually about $\frac{1}{10}$ mm. broad. In some instances this has consolidated as a fine micropegmatite, a most important observation in view of the phenomena to be described below.

The Dyke near Kahlele's. We may now pass on to the consideration of another intrusion near the central part of the Matopo granite mass. It is a much larger one than that furnishing the specimens previously referred to, running for several miles in a north and south direction through Kahlele's Old Kraal. The granite is here remarkably uniform and of the normal type prevalent throughout the Matopos, consisting of quartz, microcline, oligoclase, and biotite, with sphene, apatite, and orthite as accessories. The width of the dolerite dyke usually exceeds 100 feet, and it forms the bottom of a big depression with steep granite kopjes rising on each side to heights of several hundred feet. The tract from Fort Usher to the Blanket Mine follows this depression along the whole length of the dyke.

Microscopic Features. The normal coarser central portions of the intrusions [1352 and 1700], as seen along the road north of Kahlele's, afford examples of rather an unusual type of dolerite. Under the microscope the rock is seen to consist of olivine, enstatite, augite, and felspar in roughly equal proportions. The olivine occurs partly in good-sized grains showing a tendency to crystal outline, and partly as inclusions in the pyroxenes. It is very fresh; some lines of separated magnetite can be observed, but there is little serpentinization. The enstatite and augite occur in rather large plates. Both are quite colourless, and are apt to be penetrated to some extent by the felspars. These generally show pericline as well as albite lamellation, but are not very abundant, and the rock approaches the picrites in this respect. Small flakes of a colourless to deep-brown mica may be observed among the felspars. It may be noted here that further to the south slices show that the dyke has undergone considerable alteration. The ferromagnesian minerals are uralitized, and the production of much epidote may be observed in many places. The alteration was therefore due to deep-seated hydrothermal agencies, and not to weathering.[1] At the point we are immediately concerned with the rock is remarkably fresh, as in the specimens described above, having a black sparkling appearance in hand-specimens. As one approaches the granite margin, its texture becomes much finer, and especially towards the west side xenoliths become of frequent occurrence. They first of all appear as more or less rounded or corroded patches of quartz or felspar, or both, in the black fine-grained dolerite, but the rock passes into a type with a much lighter ground-mass, as if a considerable amount of the granitic material had been assimilated, as there can be no doubt was the case. Eventually we encounter a rock which may be regarded as contact-altered granite, and which does not look in the field as if it had been much modified.

[1] Compare *Introduction to Petrology*, p. 177.

Under the microscope this is, however, seen to be far from the truth. To the microscopic details of the specimens we may now turn.

The Mixture Rocks. [1346.] This slice is taken from a rather fine-grained rock nearer to Kahlele's Kraal than most of the others. In the hand-specimen it appears a perfectly normal dolerite, consisting of felspar and augite, and in some parts of the slice there is little to disturb such a conclusion. However, there are several large xenocrysts of felspar, one so nearly dissolved that without the evidence of the others its true nature might not be suspected. These felspars have an altered appearance, and a very peculiar mottling, evidently due to the heating they have undergone, but the cross-hatching of microcline is nevertheless recognizable. Two quartz xenocrysts about 3 mm. long also occur. The most interesting feature of the felspar xenocrysts is their recrystallization along their edges into clear felspar, contrasting sharply with the cloudy interior. This sometimes shows distinct crystal faces, and is idiomorphic towards quartz and micropegmatite. The last is somewhat abundant, and in view of the presence of xenoliths in all stages of solution, obviously derived from the surrounding granite, there can be little doubt that it results from the complete absorption of others, especially bearing in mind the relation already noted to the latter growths of felspar. The patches where micropegmatite is most abundant generally show some larger grains of quartz, and are, moreover, characterized by the presence of small biotite flakes instead of the augite of the normal doleritic patches.

Pl. I, Fig. 3 [1701]. This represents a further stage of admixture. In hand-specimens it is a black fine-grained rock enclosing many conspicuous xenoliths of granitic material. The ground-mass has under the microscope a rather granular appearance (see Fig. 3), but is permeated everywhere by fine micropegmatite. Some basic felspar remains, but biotite is the ferromagnesian mineral. Most of the quartz xenocrysts and some of those of felspar are composite. Beautiful examples are to be seen of corrosion cavities in the felspars, filled with micropegmatite, the clear felspar of the latter being in optical continuity with the remainder of the xenocryst. This is illustrated in Fig. 3, where two such cavities are shown in a crystal of oligoclase, which has the characteristic cloudy mottled appearance of all the felspar xenocrysts of this intrusion.

Slice [1703] is similar to the above. It has a very interesting feature in the presence of an orthite (allanite) crystal, which shows as an oval dark patch at the edge of Fig. 4. Orthite is an almost constant accessory in the Matopo granite,[1] and is well developed in the rock round this particular intrusion.[2] Slice [1351] is also similar. It has numerous examples of cloudy felspar xenocrysts extinguishing simultaneously with the fresh felspar of the surrounding micropegmatite, which last forms the bulk of the rock. One corrosion cavity has an edging of fresh felspar with well-developed crystal faces idiomorphic towards the enclosed micropegmatite.

[1] See *Geology of Southern Rhodesia*, 1904, p. 29.
[2] Geol. Mag., January, 1910, p. 18, and Pl. V, Fig. 10.

[1702.] This specimen has a dark-grey crystalline ground-mass, with enclosed patches of quartz and felspar, and although the rock it represents forms large masses near the edge of the dyke, it is evident they are to all intents and purposes partly absorbed granite xenoliths. It is remarkable how little basic material can be definitely identified under the microscope, though the dark colour of the rock is strong evidence of its presence. The ground-mass is made up of fine- to medium-grained micropegmatite with minute scattered biotite flakes. The cloudy felspars derived from the granite are frequently in crystallographic continuity with those of the surrounding intergrowths, and these at times show the microcline cross-hatching. Zoning can sometimes be observed, a wave of extinction starting at the outer edge of the cloudy felspar, and passing gradually across the micropegmatite fringe. The nucleus itself is free from the zoning, as are the felspars of the surrounding granite mass. A well-developed crystal of orthite, about $\frac{3}{10}$ mm. in length, is present in this slice, and shows very little alteration. Slice [1704] shows altered crystals of sphene, which, like the orthite, is a constant accessory in the granite. It may be remarked that slices 1702 and 1704 would both be taken to represent fairly typical granophyres, in Rosenbusch's sense of the term, without a knowledge of their field relations. (See Fig. 5.)

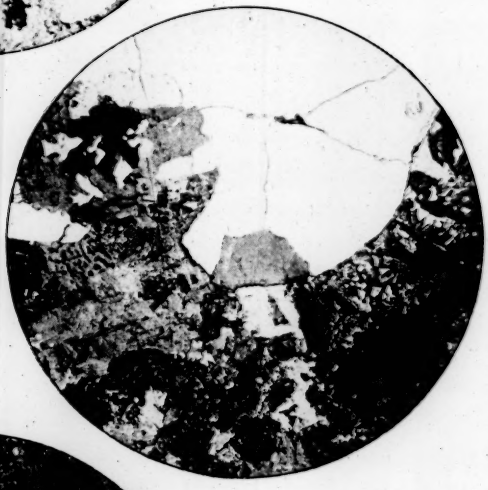
[1705.] This is made up almost entirely of granitic materials. Indeed, the ground-mass really shows no traceable doleritic materials. It is quite subordinate in amount to the xenocrysts, or phenocrysts, or whatever they are most correctly to be termed, and chiefly consists of reaction zones between the quartz and corroded felspars, which afford beautiful examples of micropegmatite (see Fig. 6). Apatite, sphene, and orthite are among the constituents of the rock as in the surrounding granite mass. Biotite is freely distributed in aggregates of small flakes, but neither in this case nor in any of the other specimens does it occur as actual xenocrysts. The original crystals have evidently always been melted down, or otherwise destroyed, and it has then crystallized out afresh amongst the ground-mass. Before closing, it may be well to remark that in no case has micropegmatite been found in any but marginal modifications of the Matopo granite, and in these latter it is always of the vermicular type which seems characteristic of rather rapid cooling under very deep-seated conditions. It was the very fact of finding, among the specimens sliced from this locality, 20 miles from the edge of the granite, what appeared to be a by no means deep-seated type of granophyre with normal micropegmatite, that led me to re-examine the spot with care the next time I travelled by.

General Conclusions. The phenomena, which I am afraid are only scantily and imperfectly described above, are in some respects closely similar to those which Professor Judd recorded[1] in certain cases which seemed to him to prove the secondary origin of micropegmatite and the growth of crystals in rocks after their solidification. Thus the cloudy central parts of the micropegmatite masses which he observed

[1] Q.J.G.S., May, 1889, pp. 175–86.

4

[1703.] Modified Dolerite, with xenocrysts. Kahlele's. × 20 diam.



5

[1704.] Composite Granophyre. Kahlele's. × 20 diam.

6

[1705.] Composite Granophyre. Kahlele's. × 20 diam.

Basic Dykes, Rhodesia.

are here well seen, as they are in a number of rocks which may be described as 'porphyrites', e.g. that of Groby, in Leicestershire. In the present case we have, however, clear field and microscopic evidence that they represent the surviving portions of crystals which have had their exteriors melted or corroded. The outgrowths are therefore, as Judd correctly surmised, of the nature of secondary enlargements long after the consolidation of the original nucleus. Where his suggestion was at fault was in regarding the regrowth as having taken place at the expense of a non-crystalline ground-mass. The outgrowths that we have been discussing are clearly due to the recrystallization under the influence of heat of the exterior portions of the original crystals, together in some cases with materials due to reactions with the surrounding crystals or with introduced substances. It need hardly be pointed out that similar phenomena might naturally be observed in basic dykes intruded among sedimentary rocks,[1] but without the guide to their interpretation furnished by the association of the acid materials with what can here be seen in the field to be obvious granite xenoliths. The light such an observation throws on the occurrences of quartz and micropegmatite among basic rocks, and upon the frequently noted association of gabbro or dolerite with granophyre, is evident. There seems little doubt that it may usually be ascribed to the partial admixture, prior to intrusion, of acid and basic materials, not necessarily from related magmas, or even entirely of igneous origin.

EXPLANATION OF PLATES I AND II.

FIG. 1. Fine-grained dolerite, within a few millimetres of a granite xenolith. Antelope Road, Rhodesia. [1737.]

FIG. 2. Granite xenolith, completely penetrated by material from the dolerite, which surrounds and corrodes every individual crystal. Antelope Road, Rhodesia. [1738.]

FIG. 3. Much modified dolerite from dyke near Kahlele's Old Kraal, Matopos, Rhodesia. [1701.] The ground-mass contains a considerable amount of micropegmatite, too fine to be distinguishable in the figure. The xenolith shown consists of two individuals of oligoclase, with a peculiar cloudy mottled appearance. One of these contains two corrosion cavities filled with rather coarse micropegmatite, their fresh felspar extinguishing with that of the xenocryst.

FIG. 4. This shows quartz and felspar xenoliths in a slightly coarser ground-mass than the previous specimen. An orthite crystal is seen as a dark patch at the edge of the slice next to a felspar xenolith. The smaller dark flakes are biotite. [1703.]

FIG. 5. A large corroded quartz xenocryst is shown surrounded by micropegmatite. The rest of the field is largely micropegmatite, too fine to show well in the figure. [1704.] Nicols crossed.

FIG. 6. This shows both quartz and felspar together with fairly coarse micropegmatite. Note the fringe of finer micropegmatite between the cloudy felspar and the adjacent quartz. [1705.] Nicols crossed.

All the figures are magnified 20 diameters.

[1] Compare G. W. Tyrrell, GEOL. MAG., August, 1909, p. 365.

III.—Glacier Motion.

By R. M. Deeley, M. Inst. C.E., F.G.S.

SIR HENRY HOWORTH in his *Ice or Water* deals in considerable detail with the various theories of glacier motion which have been propounded. His works are veritable mines of information concerning the subject of ice and water, and he is everywhere anxious to give all workers credit for the work they have done, to state their theories correctly, and if he should differ from their conclusions to do so in a kindly spirit. Among other theories of glacier motion he refers to the one for which I am responsible. Referring to this theory he says—[1]

"In the *Philosophical Magazine* for 1888 Mr. Deeley propounded what he claimed to be a new theory of glacier motion. In this paper he very rightly says 'that every change of outline suffered by a glacier, if we disregard melting and the small internal changes of bulk produced by pressure, etc., is due to the shear of ice plane over ice plane'. He further says of glacier motion: 'We have, therefore, two kinds of motion—one a bodily slide in a downward direction, and another due to the differential motion of the ice not in contact with the ground.' In order to explain the latter he postulates that constant liquefaction and resolidification is taking place within a glacier by the sun's heat penetrating it and melting certain portions, and inasmuch as a glacier has a tendency to sink in consequence of its gravity, the liquefying of certain portions of its interior will take away the support of the rest and let it sink down.

"This theory is, as Le Conte says, a modification of Professor James Thompson's. It seems to me to be based on a great many unverified premises. In the first place, the notion that sun heat can penetrate ice and melt small cavities in its interior, forming ice flowers (as was shown experimentally by Tyndall), may be true of transparent ice, like lake ice, upon which the experiment was tried, but seems to me to be extremely improbable when applied to a glacier with its broken, often snow-covered, opaque or opalescent crust and surface. Again, this process of the sun's heat penetrating a glacier and forming occasional and sporadic ice flowers in its midst would not account for the continuous flow of the whole glacier, whatever effect it might have in inducing isolated particles to move.

"Thirdly, the theory is based on the notion that glacier ice when it flows is at the melting point, and in fact Mr. Deeley says that it has been experimentally proved that it only moves at this temperature. I altogether traverse the view that anything of the kind has been proved, and the fact that the Alpine, Norwegian, and especially the Greenland glaciers all move in the winter shows it to be untenable. Lastly, and this is conclusive, if the theory were right there would not be a continually increasing differential flow from the base of a glacier to its summit and from its sides towards its centre."

It must be admitted that this is rather a sweeping condemnation of the theory. I venture to maintain, however, that Sir Henry Howorth

[1] *Ice or Water*, p. 391.

has misunderstood my meaning in some cases and in others his conclusions are unsound.

The theory propounded in 1888 is as follows: "Take a plate of steel, say 24 inches long, 3 inches deep, and half an inch thick. Firmly fix one end to a suitable support so that the steel plate shall form a girder with its greatest depth in a vertical position. Then distribute a number of weights along the length of the bar. It at once becomes deflected; that is, shear, *elastic shear*, is produced. . . . We will now drill a row of holes along the plate, and when this has been done, the girder, having been weakened, will be found to have taken a still greater amount of set. Still further increase the set by drilling several rows of holes. So far all the operations have been possible ones; but I must now draw upon the imagination somewhat, and perform operations which cannot be carried out in practice. Take the material removed from the numerous perforations in the plate, and replace it so that the plate becomes whole again. It is evident that though again solid, only that metal which formed part of the original perforated plate is in a state of strain, that portion filling the holes taking no share of the load. We will again drill a number of holes, this time in the spaces between the older perforations, and another increase will take place in the deflection of the plate. A strain will also be put upon the metal in the first series of holes bored, and, in addition, a greatly increased strain thrown upon what remains of the original plate. By repeating the operation the girder could be deformed to any desired extent, and, if necessary, such a violent strain thrown upon any one point that *local rupture* would ensue."

I also illustrated the theory by pointing out that the liquid cavities produced in ice by the sun's rays would have a similar effect upon the ice. I never, however, suggested or imagined that the few small cavities near the surface of the glacier which could be formed by the sun's heat were the cause of glacier motion, nor did I suggest, as far as I can remember, that a glacier would not move if the temperature were below the freezing-point. This seems to have been assumed because I refer to the "efficacy of *liquefaction* and *recongelation* to produce glacier motion".

Sir Henry Howorth also refers to a paper communicated by me to the Geological Magazine for 1895. In this paper it is made clear that liquefaction and recongelation are regarded as *molecular phenomena*. In the case of a non-viscous solid the molecules or atoms may be regarded as linked to each other in such a way that their motions, due to the heat of the mass, never sever the linking. It may be that when the body is strained sufficiently the vibrations of the molecules do cause a severance of the molecular attachments; but other attachments are immediately formed and the body is permanently altered in form without fracture. In other words the substance is a plastic one and can only be permanently deformed when the stress exceeds a certain figure. In the case of a viscous body the molecular linking is being constantly broken here and there by the vibrations of the molecules. Each link broken acts like the drilling of the hole in the steel plate and leads to a change of form; for the freed molecules

immediately form new and less strained linkages. The higher the temperature the greater will be the number of links broken in a given time and the more rapid will be the distortion; also the greater the stress the greater will be the distortion in the breaking of each link. It does not follow that the breaking of the molecular links will only take place at the freezing-point. It is generally believed that the higher the temperature of the body the more energetic is the motion of the average molecule or atom. Even at the melting-point some of the atoms move slowly and others rapidly, and as the temperature falls there are still molecules moving with sufficient rapidity to cause a breakage of the linkages. This conception of the cause of viscosity also explains the partial recovery of form a stressed viscous substance undergoes when the load is removed. The highly strained but unbroken linkages, on the removal of the external stress, produce an immediate elastic recovery and also a slower recovery as the strains are relieved by the constant breaking of molecular attachments.

It is clear that glacier ice is not a viscous substance in the sense that water, pitch, or alcohol are; for a crystal of ice can only be caused to shear viscously in a direction at right angles to the optic axis. In this case it would appear that the atomic or molecular linkages are broken by the vibrations in one plane only. A mass of ice built up of a number of crystalline granules, as is glacier ice, would not flow viscously if it possessed this viscous peculiarity only, for as the optic axes are in all directions they would lock each other and prevent motion. But it is certain that the molecules at the interfaces of the crystalline granules are constantly forming new linkages, for some granules are increasing in size whilst others are decreasing, there being a constant transfer of molecules from granule to granule. It is to this interchange of molecules between granule and granule that the peculiar viscosity of glacier ice is primarily due. When the stress producing flow is small the granules are of various irregular shapes and sizes and the rate of distortion is small. When the stresses are great, however, the tendency is for the interfaces of the granules to assume the form of shear planes, the granules then slowly sliding over each other without actual *fractures* being produced. The granules, however, are sheared also without fracture, and the coarseness of the granular structure thereby reduced. No doubt the effective viscosity of glacier ice depends largely upon the size and shape of the ice granules.[1] Some calculations I made seemed to prove this. At any rate the difference in the viscosity of the ice of several glaciers seemed to be much greater than could be accounted for by errors in the data.

I will now refer to Sir Henry Howorth's most conclusive argument. He says: "Lastly, and this is conclusive, if the theory were right there would not be a continually increasing differential flow from the base of a glacier to its summit and from its sides towards its centre." As a matter of fact there is *not* an *increasing differential* flow from the base to the summit and from the side to the centre. The rate of distortion is greater at the sides and bottom than it is at the upper

[1] Proc. Roy. Soc., 1908, p. 250.

surface and middle.[1] This I have shown in some detail in a previous communication. Sir Henry Howorth may mean that if my theory were correct the centre would not move more rapidly than the sides and bottom. This would, however, I venture to think, be an erroneous conclusion to draw; for the rate of distortion would depend upon the magnitude of the stress producing shear and also upon the number of the 'linkages' broken in any given time. The act of breaking a link is equivalent to the liquefaction of the molecule and the reattachment to recongelation. The maximum shearing stress, and, therefore, the maximum rate of distortion, is at the bottom of the glacier, and the force producing it is measured by the total downward component of gravity. Half-way between the base and the summit the shearing stress is one-half that at the base, whilst at the summit, on the surface of the ice, it is *nil* and there is no differential motion.

I am sure Sir Henry Howorth will excuse my pointing out that he has been led into a mathematical error by some means or other; for if he were correct my theory would be discredited.

IV.—Note on a Landslip in the Isle of Wight.

By R. H. Chandler.

THE accompanying sketch is from a photograph taken in April, 1906, of a series of landslips just east of Chilton Chine, near Brixton, on the south coast of the Isle of Wight. The cliff, which is

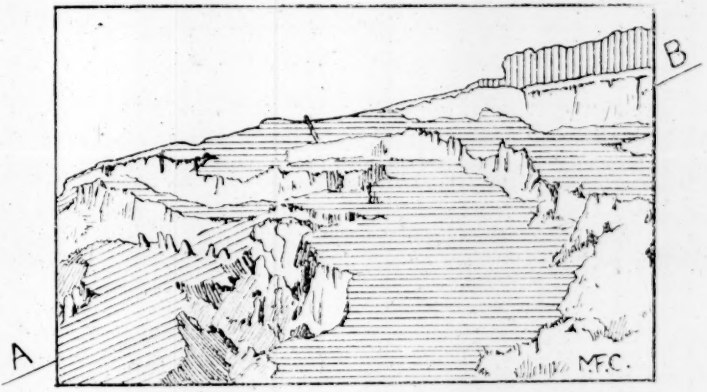


Fig. 1. Sketch of landslip. Distance from A to B about 50 yards.

composed of Brick-earth on gravel and this overlying Weald Clay, had fallen away in a series of blocks of triangular section, which were alternately base and apex uppermost; the apices in places were quite acute, and one could stride from base to base over the sharply defined apex of a clay triangle. The bases of these triangles were the grassed surface, and the apices of toughened and slickensided Brick-earth

[1] Geol. Mag., 1895, p. 408.

which stood up, perhaps, 4 feet beyond the grass; where the apex would naturally have been higher it was usually broken away and crumbled down. There were spaces between the blocks large enough for a horse to fall down and as much as 15 feet deep, at which depth the talus blocked the view. These spaces were overhung by the triangle that stood on its apex, so that the surface contour of my section is correct. At the time the photograph was taken the landslide

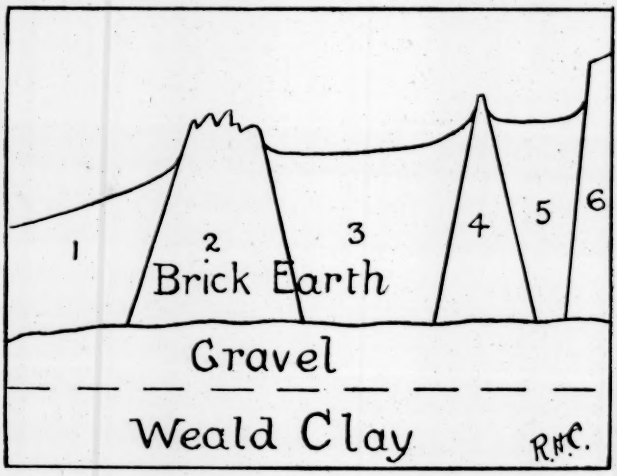


Fig. 2. Probable section along the line AB showing the relative positions of the beds. No scale.

was quite new, that is, small pieces of clay were falling from the overhanging faces and the fractures of grass and clay looked perfectly fresh. Possibly it had only occurred a few hours previously.

The cause of the landslide seems fairly evident, for water percolates through the gravel (on top of the Weald Clay) at a little above the beach level, and this undermines the overlying Brick-earth, besides which the Weald Clay is removed by marine erosion. What appears to have happened in the section here figured may be something like this: for some reason or other the mass of Brick-earth Nos. 1, 2, 3, 4, and 5 became undermined and broke away from No. 6 (which is the normal and undisturbed position of the Brick-earth). The shock of this settlement shook off the block No. 1 as a 'free surface'. Block No. 1 settled down and impinged upon the lower corner of No. 2, which caused the separation of 2 from 3. No. 3 was thus left unsupported and undercut, which caused it to separate from No. 4. No. 3 settled down and separated No. 4 from No. 5 (as 1 separated 2 from 3). The lower parts of these blocks would settle down into the gravel and water, which would render them more easily movable, and the wedges would gradually tend to drive the detached masses seawards.

V.—Some Cirripedes from the Chalk of Salisbury, Wilts.

By Thomas H. Withers, F.G.S.

ALTHOUGH the remains of pedunculated Cirripedes are comparatively rare in the Chalk of England, especially in its lower zones, one can, by careful collecting extended over a number of years, get together a fair series of the detached valves of the capitulum. Thus a very fine series of Cirripede remains has been accumulated by Dr. H. P. Blackmore, F.G.S., from the upper zones of the Chalk near Salisbury. This collection, which, through the kindness of Dr. Blackmore, I have lately had the opportunity of examining, is especially rich in the valves of *Scalpellum fossula*, Darwin, and *S. maximum* (J. de C. Sowerby). It is, of course, only on extremely rare occasions that the valves of the capitulum are found associated, but Dr. Blackmore has been fortunate enough to obtain part of the

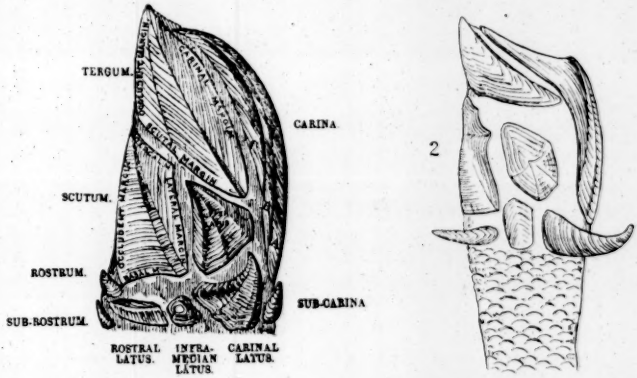


Fig. 1. Restoration of *Scalpellum fossula*, Darwin. (After Darwin.) To show position of valves, and the more primitive types of carina and scutum in which the umbo is apical, and the growth of the valves consequently directed downwards. Senonian: Norwich.

Fig. 2. Restoration of *Scalpellum magnum*, Darwin. (After Darwin.) To show the more advanced types of carina and scutum in which the umbo is subcentral, and the growth of the valves directed in opposite directions. Coralline Crag: England.

capitulum of a form probably referable to *Pollicipes glaber* (F. A. Roemer), a few associated valves of S. *maximum*, and a really beautiful example of *S. fossula* with all the valves of the capitulum in position, as well as a few of the calcified plates of the peduncle. These specimens I hope to be able to describe and figure at some future time.

The present paper contains descriptions of two species of *Scalpellum*, of which one is new, one new species of *Pollicipes*, and one of *Loricula*, all in the collection of Dr. Blackmore. Two of these, *Scalpellum Darwinianum*, Bosquet, and *Loricula expansa*, sp. nov., are of great interest from both a stratigraphical and phylogenetic standpoint.

In the earlier and more primitive forms of *Scalpellum*, the umbo of two of the typical valves of the capitulum (the carina and scutum) is apical, and the growth of the valves is consequently in one direction.

S. tuberculatum, Darwin, constitutes a further advance, for in this form the umbo of the scutum is in a sub-central position, the umbo of the carina being still apical. In the more advanced forms the carina as well as the scutum has the umbo in a central or sub-central position, and the growth of the valves proceeds in two opposite directions. As yet, only one Cretaceous species in which either the carina or scutum has this advanced type of growth has been recorded with certainty from England, namely *S. tuberculatum*. This species was collected by the late William Harris from the Chalk detritus of Charing, Kent, but unfortunately its exact age is doubtful.

The occurrence of *S. Darwinianum*, Bosquet, is therefore of great interest as being the first record of an English species in which the umbo of the carina is sub-central, and the growth consequently in two directions. The species has been found by Dr. Blackmore in the zones of *Actinocamax quadratus* and of *Belemnitella mucronata*.

Including those described in this paper, there have been nearly forty species of *Scalpellum* described from British and foreign Cretaceous rocks. Of these, only five have either the carina or scutum, or both, with the growth proceeding in two opposite directions; namely, *Scalpellum tuberculatum*, Darwin, *S. Darwinianum*, Bosquet, from the Chalk of this country; and *S. Beisseli*, Bosquet & Müller, *S. Darwinianum*, Bosquet, *S. Hagenovium*, Bosquet, and *S. radiatum*, Bosquet, from the Upper Senonian and Maestrichtian of Holland and Belgium, and other foreign localities.

The significance of this will be seen when it is noted that a much larger proportion of the Tertiary species have this double direction of growth, and among the recent species the percentage is still higher.

Loricula expansa, sp. nov., is also of much interest, since it represents a further development in the scutum, the umbo of which is situated in a much more central position than in the other forms of *Loricula*. Unfortunately the scutum is the only valve known, but owing to its great importance it is thought advisable to describe it, especially as it is represented by five examples.

It is therefore apparent that there is a close connexion between the geological age of the forms and the position of the umbo in certain valves of the capitulum, and this feature is consequently of great phylogenetic importance.

To facilitate the interpretation of the isolated valves here described, figures are given in the text in which the valves of the capitulum are in position. (See Figs. 1, 2, p. 21, and Fig. 7, p. 28.)

Scalpellum Darwinianum, Bosquet. Figs. 3, 4.

1854. *Scalpellum Darwinianum*, J. Bosquet, Les Crust. Foss. du Terrain Crétacé du Duché de Limbourg, p. 46, pl. iii, figs. 6–12.
1854. *S. Darwinianum*, C. R. Darwin, Ray Soc. Monogr. Sub-class Cirripedia, Synopsis et Index Systematicus, p. 631.
1880. *S. Darwinianum*, Th. Marsson, Mittheil. naturw. Vereine von Neu-Vorpommern und Rügen, Jahrg. xii, p. 4, pl. i, fig. 1.
1888. *S. Darwinianum*, A. Peron, Bull. Soc. Sci. Yonne, vol. xli, p. 270, pl. iii, figs. 1–4, 1887.

This most interesting species, hitherto unrecorded from the English Chalk, is represented in Dr. Blackmore's collection by five carinæ and

one right tergum. Three of the carinæ are very small and measure only about 2 mm. in length, the fourth measures 8 mm., and the fifth (Fig. 3), although slightly broken at each extremity, measures 12·6 mm. in length. The right tergum is slightly broken at the apex and basal angle, the portion remaining measuring 9·5 mm. in length and 3·6 mm. at its widest part.

Distribution.—Upper Senonian: *Actinocamax quadratus*-zone, East Harnham, near Salisbury; *Belemnitella mucronata*-zone, Alderbury and Clarendon, near Salisbury, Wilts; *Actinocamax quadratus*-zone, Reims, France; *Belemnitella-mucronata*-zone, Isle of Rügen. Upper Senonian and Maestrichtian: St. Pierre, Duchy of Limbourg, Holland. Upper Senonian: Frère, near Tongres. Maestrichtian: Sichen, Belgium.

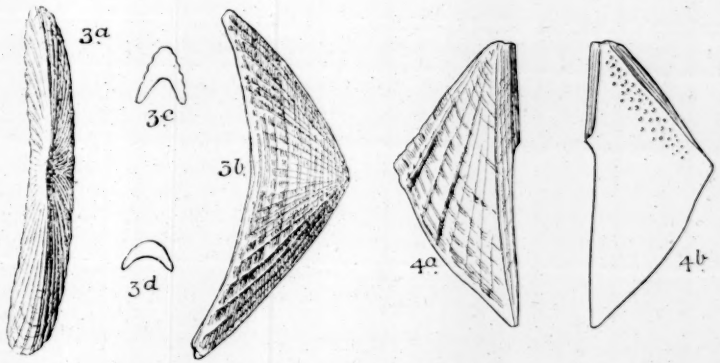


Fig. 3*a*. *Scalpellum Darwinianum*, J. Bosquet. × 4 diam. External view of carina, with umbo in sub-central position. Upper Senonian, *Belemnitella mucronata*-zone: Alderbury, near Salisbury, Wilts.

,, 3*b*. Id. Side view.

,, 3*c*. Id. Transverse section at one-third from apex.

,, 3*d*. Id. Transverse section at one-third from base.

,, 4*a*. Id. External view of right tergum. × 4 diam.

,, 4*b*. Id. Inner surface of same showing series of tubercles.

Description of Carina. Carina (Fig. 3) not quite symmetrical, being markedly convex on the left side and concave on the right, abruptly bent near the middle, umbo almost central, situated slightly nearer to the upper extremity of the valve; form linear, the upper and lower regions forming an angle of about 112°; inner margin curved; the lower region of the valve a little wider than the upper; sides of valve sharply inflected and almost flat. The roof of the carina is very narrow above the umbo, and from the umbo downwards is somewhat wider. The valve is not divided off into tectum, parietes, and intraparietes, but these parts are fused. The whole exterior surface is ornamented with raised ridges, which radiate from the umbo, and are much coarser on the roof of the carina than on its sides. These ridges are crossed by finer raised ridges, which follow the outline of the valve, giving the surface a cancellated appearance. Inner surface of valve deeply concave.

Tergum. A right tergum (Fig. 4) found at the same locality and horizon as the carina, agrees so well with the homologous valve associated with the carina of *S. Darwinianum* figured by Bosquet (1854) that I propose to describe it here as belonging to it.

Tergum obtusely angular in general outline, narrow, about two and a half times as long as wide, ornamented with several irregular, raised longitudinal ridges. Apex

and basal angle pointed. Carinal margin slightly extended for its upper third beyond the rest of the margin, and forming a narrow, almost rectangularly inflected margin, which when looked at from above is hardly discernible, so that the whole carinal margin appears to be nearly straight. Scutal margin slightly sinuous, a little longer than the occludent margin, with which it forms an obtuse angle. An obscure ridge divides the valve unequally from the apex to the basal angle. Carinal portion very narrow, wider in its upper third, and ornamented with two or three extremely fine longitudinal lines. Occludent portion at its maximum much wider than the carinal portion, and with raised ridges radiating from the apex. Of these ridges, two are much coarser than the others, one extending from the apex to about the middle of the scutal margin, and the other, which is much more raised, running near and almost parallel to the occludent margin. Inner surface of valve shows more plainly the abrupt extension of the upper third of the carinal margin. From the base of the projecting portion to the apex, and along its edge, a narrow portion of the valve is marked with fine oblique lines, which are also seen for the same extent on the opposite edge of the valve. For about a third of the breadth of the valve, parallel to the occludent margin and extending nearly its length, the inner surface of the valve is marked with a series of small tubercles.

Remarks. J. Bosquet (1854), in his original description of the carina of *S. Darwinianum*, states that the tecta or roof-parts of the carina are smoothed and flattened, the rest of the valve being ornamented with fine ribs. In the English examples, on the contrary, the whole of the valve is covered with raised ridges, these being more strongly marked on the tecta, and this seems to be the case also with the carina from the *Actinocamax quadratus*-zone of Reims represented in the figure given by A. Peron (1888). The tergum described above also presents slight differences, the most important being the position of the ridge that divides the valve into carinal and occludent portions. Bosquet figures this as situated almost in the middle of the valve, while in the English example it is much nearer the carinal margin. Both terga agree in the presence of a narrow tract of tubercles on their inner surfaces, a character which is not known in any other Cretaceous species of *Scalpellum*. The function of these tubercles is evidently closely connected with the attachment of the membrane which held together the plates of the capitulum. These differences, however, are not sufficient to justify founding a new species, since the smoothness of the tecta mentioned by Bosquet in his diagnosis of the species, and emphasized in his figure of the carina, may be due to the imperfect or different mode of preservation of the Maestricht specimens. On the other hand, it may represent a different stage in the development, and in this connexion it may be noted that the English and French forms come from a slightly lower horizon.

The carinæ of this species are very variable, the ribs in some specimens being much finer and more numerous than in others. This is also the case with two carinæ from the Maestrichtian of St. Pierre, Duchy of Limbourg, which were acquired from the author of the species, J. Bosquet, for the British Museum (Natural History), registered (I 13604, I 13605). The smaller specimen (I 13605) is ornamented with very fine and numerous ridges, the tecta not being very smooth; the larger specimen (I 13604) has much coarser and fewer ridges, and the tecta are much smoother. In the carina (Fig. 3) from Alderbury, the valve is convex on the left side and concave on the right, a feature which can be seen in the larger valve (I 13604). This, however, is not the case in the smaller valve

(I 13605), or in the other English specimens, neither does it appear to be so in the carina figured by Bosquet (1854) or that by Peron (1888).

SCALPELLUM LONGISSIMUM, sp. nov. Fig. 5.

Diagnosis. Tergum long, narrow, about three and a half times as long as wide, widest part of valve near the base, scutal margin proportionally very narrow, and formed by two straight lines which make an angle of about 140°. Surface of valve smooth.

Material. A right and a left tergum, both complete, and a portion of a right tergum. The complete right tergum has been crushed and the pieces slightly displaced, but the left tergum, although it has been broken, has been so reset that it shows its original shape. It measures 24·3 mm. in length, and its greatest width is 7 mm.

Holotype.—The left tergum (Fig. 5).

Horizon and Locality. Upper Senonian, *Actinocamax quadratus*-zone: East Harnham, near Salisbury, Wilts.

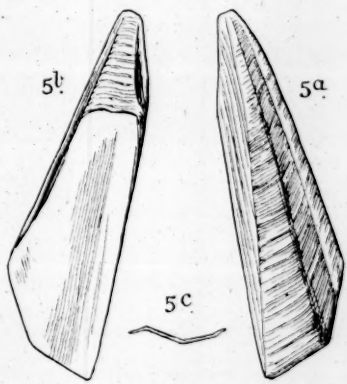


FIG. 5*a*. *Scalpellum longissimum*, Withers, sp. nov. External view of left tergum. × 2 diam. Upper Senonian, *Actinocamax quadratus*-zone: East Harnham, near Salisbury, Wilts.

,, 5*b*. Id. Inner surface of same, showing portion of valve near apex marked with fine transverse lines.

,, 5*c*. Id. Section across middle of same.

Description of Holotype. Tergum divided into two unequal portions by a well-defined ridge extending from the apex to the basal angle; the carinal portion is extremely narrow and emerges from the basal angle, widening very slowly until it reaches about three-quarters the length of the valve, and then rapidly narrows until it reaches the apex, thus forming an obtuse angle about one-fourth from the apex; the occludent portion in its widest part, which is at the angle formed by the occludent and scutal margins, is about three times the width of the widest part of the carinal portion (i.e. one-fourth from the apex); scutal margin formed of two almost equal straight lines making an obtuse angle. Occludent portion sharply bent downwards from the carinal portion, and on reaching the line from the apex to the angle of the scutal margin, becomes flattened and forms a wide flat groove or depression. This is bounded by a slip of about the same width, which rises sharply up from the depression and forms a rounded border to the occludent margin. On the carinal portion the growth-lines are very obliquely upturned, and run nearly parallel to the lower part of the carinal margin, and on the occludent portion they are more prominent than on the carinal portion, and follow the outline of the scutal margin. On the inner surface there is an extremely narrow portion of the valve

along the inner occludent margin, marked with very oblique lines, and a considerable part of the apex, marked with transverse lines, probably indicating the extent to which the valve projected freely.

Comparison with other Species. These terga are quite unlike any valves either of *Pollicipes* or *Scalpellum* with which I am acquainted. The terga which apparently come nearest to them are those of *Scalpellum maximum* (J. de C. Sowerby) and its varieties. These, however, differ much from *S. longissimum*, especially in the more pointed and produced basal angle, the pointed apex which is curved towards the carina, and in the general shape of the valves, which are much more curved, and in some specimens almost crescentic.

POLLICIPES FILOSUS, sp. nov. Fig. 6.

Diagnosis. Carina almost straight, transversely rounded, basal margin obtusely V-shaped, with basi-lateral angles somewhat produced, and the whole exterior surface ornamented with fine rounded longitudinal ridges.

Material. Two carinæ. The smaller specimen is not quite complete, but the portion preserved measures 9·3 mm. in length and 2·3 mm. in greatest width. The largest specimen is complete, but somewhat crushed, so that it is impossible to give its accurate breadth. It is 22·6 mm. long, and measured about 5 or 6 mm. in breadth.

Holotype. The larger and complete carina (Fig. 6).

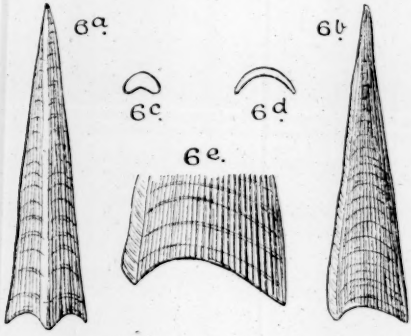


FIG. 6*a*. *Pollicipes filosus*, Withers, sp. nov. External view of carina. × 2 diam. Upper Senonian, *Belemnitella mucronata*-zone: Redlynch, near Salisbury, Wilts.

,, 6*b*. Id. Side view.

,, 6*c*. Id. Transverse section at one-third from apex.

,, 6*d*. Id. Transverse section at one-third from base.

,, 6*e*. Id. Enlarged view of external surface near base, showing direction of growth-lines, and the increased number of longitudinal ridges near its inner margin. × 4 diam.

Horizon and Locality. Upper Senonian, *Belemnitella mucronata*-zone: Clarendon and Redlynch, near Salisbury, Wilts.

Description of Holotype. Carina almost straight, long, narrow, widening very gradually from the apex, extremely convex transversely, obscurely carinate, inner margin straight; apex sharply pointed; basal margin obtusely V-shaped, with basi-lateral angles produced into spur-like processes; parietes narrow and slightly inflected. Valve extremely thin near its base, gradually becoming thicker towards

the apex; and probably projected freely to some extent. The lines of growth are directed upwards from the middle of the carina, where they are obtusely V-shaped, and then curve downwards to the inner margin of the parietes, whence they are abruptly and obliquely inclined towards the apex. The whole exterior surface is ornamented with fine, rounded, longitudinal ridges, which are finer and more numerous near the inner margin of the valve.[1]

Comparison with other Species. The carina described by Darwin as *Pollicipes striatus* (1851, p. 70, pl. iv, fig. 5) agrees with *P. filosus* in being longitudinally ridged, but disagrees in being plainly carinate, and the longitudinal ridges are not so fine, rounded, or so closely set. *P. filosus* is also strongly convex in transverse section, while *P. striatus* is flatly arched and almost triangular. *P. filosus* may be compared with the carina of *P. glaber*, F. A. Roemer (1841, p. 104, pl. xvi, fig. 11), and the two carinæ doubtfully referred by Darwin (1851, p. 58) to his *P. Angelini*. These latter valves, originally in the Fitch Collection, are now preserved in the Norwich Museum. Both in *P. glaber* and *P. Angelini* the direction of the growth-lines almost exactly agree with *P. filosus*, and consequently the three species have their basi-lateral angles produced into short spurs. They differ from *P. filosus* in being much wider and shorter, plainly sub-carinated, flatly arched transversely, and in their surface not being covered with numerous fine longitudinal ridges. One of the two carinæ referred by Darwin to his *P. Angelini* agrees more closely than the other with *P. filosus* in the direction of the growth-lines, and this specimen has a few flattened longitudinal ridges near its apex; but the rest of the valve is smooth, and differs in the characters mentioned above.

LORICULA EXPANSA, sp. nov. Fig. 8.

Diagnosis. Scutum smooth, slightly longer than wide, with the umbo situated nearly in the middle of the occludent margin, and a single well-marked groove extending from the umbo to near the top of the tergo-lateral margin.

Material. Two left and three right scuta, all nearly perfect. The complete left scutum, which is the largest, measures 7 mm. in length and 5 mm. in breadth.

Holotype. The left scutum (Fig. 8).

Horizon and Locality. Upper Senonian, *Actinocamax quadratus*-zone: East Harnham, near Salisbury, Wilts.

Description of Holotype. Left scutum sub-triangular in general outline, extremely thin, slightly convex; occludent margin slightly rounded in its upper part, dropping rapidly down in an almost straight line to the rostral angle, the lower part of the occludent margin being almost at right angles to the basal margin; the upper part of the occludent margin suddenly rises up from a groove, which extends from the umbo to near the top of the tergo-lateral margin; basal margin straight, almost at right

[1] Since writing the above description, I have been shown by Dr. H. Woodward some Cirripede remains from the collection of Mr. R. M. Brydone, F.G.S. Among the specimens are two portions of carinæ of *Pollicipes filosus*, together with a tergum which, judging from its ornamentation, also belongs to *P. filosus*. These specimens came from the *Belemnitella mucronata*-zone of Portsdown, Hants. One of the portions of carinæ represents the upper half of a valve about the same size as that of the holotype. It agrees exactly in its external form and ornamentation, but the upper portion is much more solid, and the character of its inner surface shows that the valve must have freely projected for about one-fourth of its length.

angles to the tergo-lateral margin; tergo-lateral margin nearly straight, slightly rounded at the top towards the occludent margin; umbo nearly in the middle of the occludent margin, slightly nearer the rostral angle. The finely-marked and closely-set growth-lines follow the outline of the basal and tergo-lateral margins, and on reaching the groove, which runs almost parallel to the upper part of the occludent margin, bend towards the margin. The inner surface of the valve along the inner occludent margin rises up in a thickened band, being much thicker nearer the middle, and forming a raised ridge overhanging the thinner part of the valve, thus making a pit or depression for the attachment of the adductor scutorum. This thickened ridge, especially near the middle, is marked with fine oblique lines.

Remarks, and Comparison with other Species. Since the umbo in the scuta described above is sub-central, and the growth consequently in

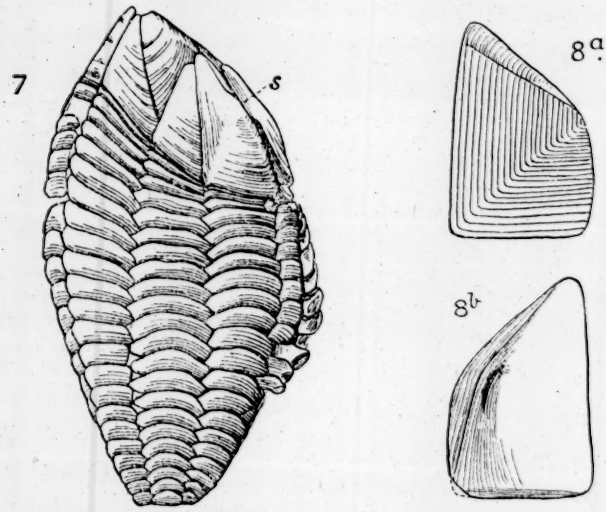


Fig. 7. *Loricula Darwini*, H. Woodward. Reproduced here to show position of scutum (*s*), in which the umbo is situated nearest the apex, and the upper part of the valve much attenuated. × 2 diam. Turonian, *Rhynchonella cuvieri*-zone: Cuxton, near Rochester, Kent.

Fig. 8*a*. *Loricula expansa*, Withers, sp. nov. External view of left scutum, with umbo in sub-central position. × 4 diam. Upper Senonian, *Actinocamax quadratus*-zone: East Harnham, near Salisbury, Wilts.

,, 8*b*. Id. Inner view of same, showing pit for adductor muscle.

two opposite directions, it was at first thought that the plates belonged to an undescribed form of *Scalpellum* allied to *S. tuberculatum*, Darwin (1851, p. 43, pl. i, fig. 10), and *S. cretæ*[1] (Steenstrup) (1837, p. 359; 1839, p. 399, pl. v, figs. 1–3), in which the umbo is also sub-central, and not apical as in the more primitive fossil species of *Scalpellum*. They differed much, however, from those species in the general shape and ornamentation of the valves, and on comparing them with the corresponding valves in *Loricula* it was at once apparent that they agreed more closely with that genus. Examination of the scutum in *Loricula pulchella*, G. B. Sowerby (1843, p. 260, figs. 1, 2), and

[1] Good descriptions and figures of the valves of this species are given by Darwin (1851, p. 45, pl. i, fig. 11).

L. Darwini, H. Woodward (1908, p. 493, fig. 1), shows that, as in our specimens, the tergo-lateral and basal margins are nearly straight and almost at right angles to each other, differing much in this respect from the scutal valves of *Scalpellum*, to which the genus *Loricula* is most nearly related. Further, in *Loricula* the occludent margin of the scutum is convex, the umbo is sub-central, and the valves extremely thin and slightly convex, characters also observed in the scuta described above. The inner occludent margin of the scutum is much thickened in *Loricula*, especially in the region of the umbo, and this is also the case in the valves before us, leaving no doubt that they are rightly ascribed to the genus *Loricula*.

Darwin (1851, p. 84) hazarded the opinion that in *Loricula* the lateral valves of the capitulum must have been present on both sides, and in support of this view Dr. H. Woodward (1908, p. 495) pointed out that in the specimen of *L. Darwini* figured by him, and in the example of *L. pulchella*, var. *minor*, figured by Fritsch & Kafka (1887, p. 2, pl. i, fig. 2), the inner margin of the under scutum could be seen projecting from beneath the occludent margin of the upper scutum. Decisive proof of the paired nature of the lateral capitular valves in this genus had, however, already been given by Whiteaves, for in the holotype of his *L. canadensis* (1889, p. 190, pl. xxvi, figs. 4, 4*a*) the upper lateral series of capitulum plates have been either partially or completely broken away, showing underneath the inner surfaces of the scutum, tergum, carinal latus, and the upper or middle latus. The under row of sub-rostral (or sub-scutal) plates of the peduncle can also be seen projecting from beneath the upper row in the figured example of *L. Darwini*.

So far, then, there is conclusive proof that the three lateral plates of the capitulum, as well as the row of sub-scutal plates of the peduncle, were present on both sides of *Loricula*; but whether the three central rows of peduncular plates are also present on the under side is still doubtful. In fact, after removing the chalk from beneath one of the three specimens of *L. Darwini* studied by him, Dr. H. Woodward found that the three principal (central) rows of the elongate scales of the peduncle were absent. He then suggested that they were not developed upon the under side of the peduncle, but that the animal was fixed to the Ammonite shell, to which *Loricula* has always been found attached, along the margins formed by the under row of the carinal and sub-rostral (or sub-scutal) valves. Bearing on this question is a fact which does not appear to have been attended to. Among the specimens of *L. pulchella* figured by Fritsch & Kafka (1887) and those of *L. Darwini* studied by H. Woodward (1908), some show the right side uppermost, with the scutum on the left hand, and others the left side uppermost, with the scutum on the right hand. Although it appears probable from this that the whole of the peduncular valves were developed on both sides of *Loricula*, it is by no means conclusive proof, since it may be quite accidental as to which side of the animal was developed uppermost, in the same way that certain lobsters have the 'crushing chela' developed on the right side and others on the left.

L. expansa differs from all other species of *Loricula*, including

L. lævissima, Zittel (1884, p. 589, fig. 4), from the Upper Chalk of Dülmen, Westphalia, in that the scutum is much broader in proportion to its length, and in the umbo being situated in a much more central position. *L. Darwini*, H. Woodward, differs from *L. expansa* in the upper portion of the valve being much narrower and attenuated, and in the smaller convexity of the occludent margin. Moreover, the umbo is situated nearer the apex, and is much more prominent: a feature of phylogenetic importance.

In the primitive forms of *Loricula*, the umbo of the scutum must have been apical and the growth of the valve directed downwards. *L. Darwini*, H. Woodward, from the Turonian (*Rhynchonella cuvieri*-zone), is a further advance in which the growth of the scutum has been directed both downwards and upwards beyond the umbo, which is situated a short distance from the apex. The umbo is still prominent, and the upper portion of the valve is much attenuated. *L. expansa*, which comes from the Senonian (*Actinocamax quadratus*-zone), a much higher horizon, represents a still further stage in the development of the scutum, as might be expected. In this form the umbo is in a more central position, slightly nearer the base of the valve, and since the portion of the valve above the umbo is developed to a greater extent and is wider than in *L. Darwini* the umbo is consequently inconspicuous.

In conclusion, I have to express my indebtedness to Dr. H. P. Blackmore for allowing me to describe these specimens, and to thank Dr. F. A. Bather, Dr. W. T. Calman, and Mr. C. P. Chatwin for help in connexion with this paper.

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VI.—On the Origin of the Cylindrical Cavities in certain Sandstones of the Fayûm, Egypt.

By H. J. Llewellyn Beadnell, F.G.S.

In an article published in a recent number of this journal,[1] Dr. Henry Woodward discusses the origin of the curious cylindrical cavities which occur in such profusion in certain concretionary blocks of sandstone and on exposed rock-surfaces at two distinct levels in one or two localities in the Fayûm depression. These perforated rocks, first noted by Schweinfurth, were examined by me some ten years ago and referred to as "apparently the work of marine boring mollusca" in my memoir on the region in question.[2] Both Dr. Schweinfurth and I had considerable misgivings in regarding the cavities in question as shell-borings, but in my case, and I believe in his also, this explanation appeared to involve fewer difficulties than any other which suggested itself.

Dr. Woodward, after comparing these cylindrical cavities with certain reed-casts found by Mr. J. E. S. Moore on the shores of Lakes Kivu and Tanganyika, pronounces that the perforations in the rocks of the Fayûm are identical in character with the latter, and concludes that they represent the casts of reeds which grew on the shores of the existing lake, the Birket el Qurûn, or on those of its more extensive predecessor, Lake Moeris.

Knowing Dr. Woodward's achievements in the interpretation of obscure fossil remains—witness his solution of the problem of the Sherringham flint pebble—I hesitate to question his verdict in the case of the Fayûm perforations. His explanation would, indeed, be more than welcome, as it would to some extent remove a difficulty arising from the assumption that these cavities are the work of marine boring mollusca, i.e. the necessity for admitting a considerable submergence of the region in Pliocene or post-Pliocene times.[3]

[1] "On some supposed *Pholas*-borings from the Shores of Birket el Qurûn, the ancient Lake Moeris, of the Fayûm, Egypt": Geol. Mag., September, 1910, pp. 398–402.

[2] "The Topography and Geology of the Fayûm Province of Egypt": Survey Department, Cairo, 1905.

[3] Submergence of the region in Middle Pliocene times to a level of between 60 and 70 metres (above present sea-level) is, I think, satisfactorily established on the evidence of the marine shell-bearing deposits of Sidmant, etc. Submergence to a level of 170–80 metres rests at present on somewhat unsatisfactory grounds, mainly (*a*) the supposed shell-borings at about 112 metres, and (*b*) the remarkable gravel terraces extending up to 180 metres above present sea-level.

Were I able to compare specimens of the Lake Kivu reed-casts and the Fayûm perforations, and had I at hand the original notes which I made when surveying the Fayûm, I might be in a position to accept or disprove Dr. Woodward's explanation without further consideration. As it is, I venture to ask the following questions:—

1. Would actual casts of the stems of reeds similar to those found at the present day on the shores of the lakes in question show close resemblance to the Fayûm perforations? Do the latter exhibit traces of the longitudinal striæ or of the segment-rings which occur at intervals along the stems? Both striæ and rings are, if I recollect rightly, very well marked in the semi-fossil siliceous reeds which are occasionally found on (presumably weathered out of) the ancient high-level deposits of the Fayûm lake.

2. Would not a true cast of a portion of a reed be of almost constant diameter throughout, and is it not a fact that the individual perforations in the Fayûm rocks vary considerably in diameter from point to point, showing concentrically arranged alternating ridges and hollows? My recollection that such is the case seems confirmed by the illustration in the paper, though the appearance may, of course, only be due to the concentric lines used for shading.

3. Do the reeds taper gently at the root as do those of the cavities of which the terminations are visible? And do the latter show any traces of the rootlets?

4. Assuming the above points can be satisfactorily disposed of, does not the theory that the Fayûm perforations represent reed-casts absolutely depend on the truth of the assumption that the concretionary and other blocks of sandstone, etc. (in which the perforations occur), actually represent portions of the material which accumulated round the bases of the reeds, while the latter were growing on the margins of the modern Birket el Qurûn or its predecessor Lake Moeris?

5. What, may I ask, is the evidence for such assumption? My impression is that the concretionary and other sandstones and sandy limestones in which the perforations occur belong to definite bands of the marine Middle Eocene formation. They are certainly so referred to in my memoir (see pp. 43, 71–3), and I am not aware of any evidence having since been met with which would necessitate a modification of this opinion. Dr. Andrews' statement "that the huge concretions, or globular masses of sandstone—honeycombed with vertical borings—represent in all probability the actual bases where these reeds formerly grew",[1] requires substantiation before it can be accepted as disposing of and replacing the above-mentioned view.

Without in any way criticizing Dr. Woodward's conclusion that the Fayûm perforations are not the work of boring molluscs, I submit that it is essential, before seeking to establish their identity with reed-casts, to bring forward satisfactory evidence that the rocks in which the perforations occur are of lacustrine origin, and not weathered-out or exposed portions of the marine strata of the Middle Eocene formation.

[1] See p. 401 of Dr. Woodward's article.

REVIEWS.

I.—Outlines of Geologic History, with especial reference to North America. By Bailey Willis and Rollin D. Salisbury. 8vo; pp. viii, 306, with numerous text-illustrations. Chicago University Press and Cambridge (England) University Press, 1910.

In the Geological Magazine for July, 1906 (p. 328), we drew attention to the very interesting *History of American Geology* then published by Mr. G. P. Merrill. That volume dealt with the gradual growth of knowledge, since 1785, historically and biographically.

The present volume consists of "A series of essays involving a discussion of geologic correlation presented before Section E of the American Association for the Advancement of Science in Baltimore, December, 1908". The symposium was organized by Mr. Willis, who also prepared the instructive series of palæographic maps which are interspersed in the text; and the volume has been edited by Professor Salisbury. It may be added that the several chapters have appeared in the *Journal of Geology*, and are now bound together for the convenience of geological students; and that the volume will be welcomed as containing the results of much research and important philosophic suggestions with regard to the distribution of life in the strata and the principles of correlation.

Mr. C. R. Van Hise, in the opening chapter, deals with the principles of classification, with the nature, sequence, and continuity of formations, and with unconformities and deformations. He considers that pre-Cambrian rocks may be grouped into Archæan and Algonkian, and that these two major divisions are general, if not worldwide: the Archæan dominantly igneous, largely volcanic and submarine; the Algonkian mainly sedimentary, and laid down when "essentially the present conditions prevailed on the earth". The subdivisions of the Archæan into Laurentian and Keewatin are purely lithological, the one consisting mainly of plutonic acid rocks, the other largely of volcanic basic rocks.

Professor Frank D. Adams follows with an essay on the basis of pre-Cambrian classification, urging that a threefold division is needed. He applies the terms Eo-, Meso-, and Neo-Proterozoic, the first to the Archæan (of Van Hise), the second to Lower and Middle Huronian, and the third to Upper Huronian or Animikie–Nastapoka and Keweenawan–Athabasca. These three major periods are in the opinion of Professor Adams separated by great unconformities or epochs of diastrophism—epochs which afford "a basis of correlation of great value and importance". Mr. Van Hise rightly objects to a 'zoic' classification, which is unsupported by fossil evidence.

In the next essay Mr. C. D. Walcott discusses the evolution of early Palæozoic faunas in relation to their environment, and points out that although the traces of pre-Cambrian life are very meagre, they "are sufficient to indicate that the development of life was well advanced long before Cambrian time began". Thus the characteristic fossil of the known pre-Cambrian fauna "is *Beltina danai*, a Crustacean probably more highly organized than the trilobite. The associated

annelid trails indicate that this phase of the fauna was also strongly developed. Stratigraphically, this fragment of what must have been a large fauna occurs over 9,000 feet beneath an unconformity at the base of the upper portion of the Lower Cambrian in northern Montana".

In support of his contention that the Cambrian faunas were profoundly influenced by their environment, Mr. Walcott observes that in the restricted waters of the Lower Cambrian the known Brachiopods (of the entire world) were represented by twenty genera and seventy-five species, whereas in the expanding seas of the Middle Cambrian thirty-one genera and 243 species are known to have existed.

The physical and faunal evolution of North America during Ordovician, Silurian, and early Devonian time is dealt with by Professor A. W. Grabau; and he is followed by Mr. Stuart Weller, who discusses the correlation of the Middle and Upper Devonian and the Mississippian faunas of North America. In these articles the distribution of the faunas, the invasions of forms from other areas, and their dependence on sedimentary conditions are discussed; and Professor Grabau describes the effects of 'regressive overlap' or 'off-lap' when the area of sedimentation was lessening. Mr. Weller remarks that "All questions in correlation become progressively more complex as the territory occupied by the faunas under consideration is extended"—their history, in fact, has to be considered biologically, geographically, and geologically.

Mr. G. H. Girty writes on the Upper Carboniferous or Pennsylvanian, and in the course of his essay observes that "The Upper Carboniferous faunas of Western North America have a facies markedly different from those of the eastern part, and are closely comparable to the corresponding faunas of Asia and Eastern Europe". The author doubts whether the Kansas Permian and the Russian Permian were contemporaneous; the weight of evidence, as presented by invertebrate palæontology, appears to him to favour the view of the pre-Permian age of the Kansas deposits.

Mr. David White discusses the evidence of the Upper Palæozoic floras, their succession and range, and the changes brought about by great diastrophic movements. Thus the extensive orogenic movements in Europe stimulated the evolution of the Permian flora, whereas "in the Appalachian trough, where environment was but little affected by orogeny, and where sedimentation was uninterrupted, there is only gradual change, many of the Stephanian [Carboniferous] types persisting far up in the Dunkard formation" or Permian of South-Western Pennsylvania. The plants do not appear to differ in kind, whether found in the grey limestone-bearing strata or in the red rocks that are nearly devoid of limestones.

The faunal relations of the early air-breathing vertebrates form the subject of an essay by Dr. S. W. Williston, who discusses the evidence of continued intermigration of land animals between the eastern and western continents. Then follow a series of articles on the succession and distribution of later Mesozoic Invertebrate faunas in North America, by Mr. T. W. Stanton; on the succession

and range of Mesozoic and Tertiary floras, by Mr. F. H. Knowlton; and on the conditions governing the evolution and distribution of Tertiary faunas, by Mr. W. H. Dall. Marine, brackish-water, and freshwater strata are dealt with, and the evidence of the assemblages of fossils that existed under different physical and climatic conditions is discussed in reference to their value in indicating geological time.

In an account of the environment of the Tertiary faunas of the Pacific coast of the United States Mr. Ralph Arnold points out that "Many of the movements occurring throughout the Tertiary were of local extent, and, for that reason, correlation on a basis of diastrophism, unsupported by palæontologic evidence, is extremely hazardous".

The correlation of the Cenozoic through its mammalian life is discussed by Professor H. F. Osborn, who remarks that "The sea borders of the United States may be correlated with each other and with those of Eurasia in Cenozoic times through their invertebrate life, but for the vast interior of the American continent we must depend chiefly upon the mammals and in a less degree upon the reptiles, fishes, insects, and plants".

The Physical Geography of the Pleistocene with reference to the correlation of the formations, is the subject of an interesting article by Professor Salisbury. Mr. D. T. Macdougal then deals with the speculative subject of the Origination of Self-generating Matter and the influence of aridity upon its evolutionary development. Finally Professor T. C. Chamberlin explains Diastrophism as the ultimate basis of Correlation.

The absence of an index to this volume is unfortunate.

II.—Principles of Chemical Geology. By James Vincent Elsden, D.Sc., F.G.S. London: Whittaker & Co., 1910.

THE title of this work will recall to the mind of geologists the ponderous volumes of Bischof, which in their day held a high place in geological literature. Dr. Elsden's book, however, is a small, compact volume, and deals mainly with aspects of chemistry that were not recognized in Bischof's time. It is an exposition of the results attained by physical chemists in so far as they are directly applicable to problems of mineralogy and geology. The subject is treated from the standpoint of the equilibrium law formulated by Le Chatelier in 1884, and in successive chapters such questions as viscosity, diffusion, vapour pressures, eutectics, and crystallization of solid solutions are dealt with. The treatment is necessarily brief, yet the exposition is clear and the numerous references to original papers make the book useful to advanced students who desire a further acquaintance with the subject.

The services that physical chemistry has rendered to geology in the hands of masters of the science such as Van't Hoff, Ostwald, Tammann, and Roozeboom are very great. In every way the best example of the value of this line of investigation is the work of Van't Hoff and his pupils on the Stassfurt salt deposits. There is

good reason to hope that in the future such questions as the origin and structure of igneous rocks will in the simpler cases at any rate receive physico-chemical solutions. Much work must be done before that day comes, but we have already an earnest of the results in the work of Vogt and the chemists of the Carnegie Institution in Washington. It is becoming almost a necessary part of the education of every geologist that he should be acquainted with the main principles of physical chemistry as applied to geology.

Dr. Elsden's experience as a teacher and his original work as a petrologist have specially qualified him for this task. The book condenses into a small space information gleaned from a wide variety of sources. It is thoroughly up to date, and the only errors we have noticed in it are a few printers' errors. It may be strongly recommended to all students not only for the accuracy of its contents but also for the fairness and judicial caution with which it handles such thorny subjects as the origin of magmas by diffusion and the sequence of crystallization in igneous rocks.

J. S. F.

III.—The Geology of New Zealand: an Introduction to the Historical, Structural, and Economic Geology. By James Park, Professor of Mining and Mining Geology in the University of Otago, etc. 8vo; pp. xx, 484, with geological map, 22 full-page plates and maps, and 140 text-illustrations. London: Whitcombe and Tombs, Ltd., 1910.

WITH the ever-increasing volume of geological literature we welcome a summary of what is known regarding the main features in the geology of New Zealand, especially as the work is written by one who has taken an active part in the geological survey of the country and in the practical applications of the science. The very useful bibliography given by the author extends over 56 pages, and in preparing it he acknowledges his indebtedness to Dr. Wilckens of Bonn University.

New Zealand possesses representatives of nearly all the main geological systems, although the author is not quite right when he says that the record is "more complete and varied" than that of Australia. The Devonian system, at any rate, is not admitted by him into the New Zealand table of sedimentary formations. Some of the gneisses and crystalline schists of the Maniototo Series were regarded by Hutton as pre-Cambrian or Archæan, but the rocks which are admittedly the oldest in New Zealand are grouped by the author as Cambrian, as they are closely associated with graptolite-bearing rocks of Ordovician age. Again, the equivalents of the Oligocene are not recognized in the New Zealand series.

In the classification of the strata "it is generally conceded by New Zealand geologists that the chief formations should be distinguished by Maori names", and these are applied by the author both to the systems and subdivisions, from the Cambrian to the Pliocene, the European time-divisions being likewise indicated. The progressive

succession in the forms of life corresponds generally with that of Europe, but "obviously there may exist homotaxial parallelism without synchronal agreement". Thus it is stated, on the authority of Hutton, "that several genera of marine mollusca that appear in the Eocene of Australia did not reach New Zealand until the Miocene and Pliocene periods." But how came *Cardium striatulum*, Sow., to be recorded from the older Pliocene (Awatere) Series? Here we may mention that we miss a reference in the body of the work to the sponge-remains, described by Dr. G. J. Hinde and Mr. W. M. Holmes, from the Lower Tertiary strata near Oamaru, although the title of their paper is given in the Bibliography.

Silurian rocks are represented by the Wangapeka Series, which has yielded, according to McKay, *Calymene Blumenbachii*, *Homalonotus Knightii*, and other fossils. The Te Anau Series, next in succession, rests unconformably on the older rocks, and is grouped with the Carboniferous, although it contains "no internal evidence of its age", but it is followed by fossiliferous rocks of the Carboniferous period. In upward succession the various formations and their fossils are described, together with the intrusive and volcanic rocks associated with them. In the Hokonui system, Permian to Jurassic, there are no traces of contemporary volcanic action, but "the volcanic activity which began in the Upper Cretaceous epoch has continued with little cessation up to the present day". It is interesting to note the occurrence of greensands and of chalky limestone and chert in the Cretaceous rocks. The Eocene and Miocene formations are the principal coal-bearing strata, the former yielding anthracite, bituminous, brown, and pitch coals, and the latter yielding brown coals. Coal is also found in Jurassic and Cretaceous strata. The author estimates that the available amount of coal (excluding seams less than 2 feet thick) is about one thousand million tons, and that it is likely to be exhausted in 140 years or less. He deals also with the other mineral products—gold, iron-ore, building-stones, etc.—and remarks that "the conservation of its mineral resources will soon be the chief care of every civilized country".

The faults and physical changes which have effected the area of New Zealand are duly described. A full and interesting account is given of the Pleistocene glaciation, during which the invading ice-sheet exceeded 7,000 feet in thickness. Raised beaches, old lake beaches, post-glacial fans, and other phenomena are likewise described.

Brief accounts are given of the Recent period, which is divided into the Moriorian (Neolithic) and Dinornian, with the *Dinornis* and other recently extinct birds. Brief also are the descriptions of the geysers and hot and boiling springs of water and mud; both hot and cold mineral springs are regarded as possessing valuable curative properties.

The illustrations comprise some very good pictorial views and photographs of fossils, many sketches of fossils, some diagrammatic, and longitudinal sections. There is also a capital index. We notice a few misprints: thus *Amusium* is spelt throughout *Amussium*.

IV.—Causal Geology. By Professor E. H. L. Schwarz, A.R.C.S., F.G.S. Blakie and Son, Ltd.

THIS work treats of the origin of the earth, of the source of the earth's rocks, the atmosphere and oceans, and of the processes and agents which induce changes on the earth's surface. It may be said to be a vindication and elaboration of the planetismal hypothesis of Chamberlin. The author has evidently given much attention to the problems of causative geology, and, in addition to the results of personal observation, he has collected a formidable array of facts and statistical data as evidence of the various hypotheses he propounds or theories he supports. At the same time, the subject at his hands has received somewhat unequal treatment, and his reasoning is not always easy to follow.

The book is one which reflects the working of a scientific mind, but it is felt that unconsciously the author has now and then correlated the obvious with the obscure, and placed uncontroverted facts side by side, and on the same plane, with mere conjectures. Some of his deductions thus seem hardly warranted, but apart from the controversial portion of the work, which in itself is of much interest, the book is full of scientific facts and observations from cover to cover.

It is well printed, and the illustrations, of which there are thirty-two text-figures and several plates, are exceedingly clear and well reproduced.

H. H. T.

V.—The British Carboniferous Orthotetinæ. By Ivor Thomas, B.Sc., Ph.D. Memoirs of the Geological Survey of Great Britain: Palæontology, Vol. I, Part II, pp. 83–134, and Plate XIII. 4to. London, 1910. Price 2*s*.

IN the Geological Magazine for February, 1909 (p. 76), attention was drawn to the publication of Dr. B. N. Peach's *Monograph on the Higher Crustacea of the Carboniferous Rocks of Scotland*. The present memoir or monograph is paged in continuation of the volume of which that work was the first part.

The sub-family Orthotetinæ belong to the Brachiopod family of Strophomenidæ, and the aim of the author is to determine more particularly the British genera and species that belong to the sub-family. The genera now recognized are *Meekella*, *Orthotetes*, *Derbyia*, *Schellwienella*, *Schuchertella*, *Streptorhynchus*, and *Geyerella*, all except the last-named (which is a Permian genus) occurring in British strata. *Schellwienella* is a new genus now described by the author. The genotype is *Spirifera crenistria*, Phill., a familiar species, which like many another has passed through various phases of nomenclature, at one time known as *Streptorhynchus crenistria*, at another as *Orthotetes crenistria*. The author, however, shows that the form figured by Davidson as *Streptorhynchus crenistria* is a *Schuchertella*; and as he remarks, "It is inevitable that the application of more critical methods and the acquirement of fresh evidence, both morphological and stratigraphical, should lead, from time to time, to revisions of classification

and consequently, to some extent, of nomenclature." The difficulty to the geologist is that the more the genera and species are split up the less agreement there appears to be about them, and that in course of time palæontologists are likely to bury themselves in a mass of detail. The present work is indeed drawn up on the lines of the most progressive palæontology, by an earnest and skilled worker, whose care is beyond praise and whose conclusions are probably as sound as could be. The more interesting stratigraphical results may be given in the author's words: "Regarding the general distribution of the genera it may, therefore, be said that *Schellwienella* is found throughout the Carboniferous Limestone and in the Millstone Grit of this country and is known on the Continent from the Lower and Middle Devonian rocks. The so-called '*Orthotetes*' *umbraculum* of the British Devonian deposits probably also belongs to this genus, but is usually so badly preserved as to render diagnosis uncertain. *Schuchertella* is found in the Carboniferous Limestone and Millstone Grit, while *Derbyia* occurs in the Carboniferous Limestone, especially in the upper part, and in the Millstone Grit. *Orthotetes* is only known in this country from the Coal-measures. *Meekella* has been found in the upper deposits of the Carboniferous Limestone and in the Millstone Grit, and *Streptorhynchus* is known chiefly from the Permian rocks, but occurs also in the higher beds of the Carboniferous Limestone." An excellent plate of figures is given.

VI.—Guide to the Geological Model of Ingleborough and District. By Aubrey Strahan, M.A., Sc.D., F.R.S. Memoirs of the Geological Survey, England and Wales. 8vo; pp. iv, 17, with 2 plates and 1 text-figure. 1910. Price 4*d*.

In the Geological Magazine for June, 1906 (p. 275), we drew attention to Dr. Strahan's *Guide to the Geological Model of the Isle of Purbeck*, an area comparatively simple in plan, but full of interesting and instructive features. In the Ingleborough district the author has to deal, not only with far bolder features, but with unconformities and disturbances of great magnitude. The lower grounds are occupied by a portion of the Ingleton Coal-field, the uplands by Carboniferous Limestone and Yoredale rocks, with the grand outlier of Millstone Grit which forms the summit of Ingleborough. The uplands are trenched by certain broad valleys that exhibit Silurian, Ordovician, and older rocks (the 'Ingleton Series'), which may be of pre-Cambrian age. The general relations between the physical features and geology are strikingly shown in the two plates. One depicts the model in plain form without names; the other is an excellent colour-printed geological map of the area, without Glacial drift. The Craven fault, which is reckoned to cause a displacement of more than 5,000 feet near Ingleton, and some other lines of disturbance, are clearly indicated by the physical features.

The structure of the ground is also illustrated by a longitudinal section across Ingleborough and the Ingleton Coal-field. This would have been more ready of comparison with the map had it been drawn from south-west to north-east, instead of in the opposite direction.

The author gives a concise account of the succession of the strata, and of the disturbances and erosion whereby the present structure and physical features have been built up and sculptured, attention being drawn to the interesting glacial phenomena, the caves, swallow-holes, and underground water-channels in the Carboniferous Limestone.

VII.—Brief Notices.

1. Maryland Geological Survey.—The eighth volume of general reports issued (1909) under the superintendence of Dr. W. Bullock Clark, State Geologist, like the former volumes, is admirably printed and illustrated. The subjects of road materials and road-construction are further dealt with, and views are given of roads before and after improvement under State aid. There is a detailed report on the mineral industries, accompanied by a useful table of the geological formations of the State and their economic products; there is also a special report on the limestones with reference to their use in the manufacture of lime and cement.

2. Natural Resources of Maryland.—The first Report of the Conservation Commission of Maryland for 1908–9 is of much interest and importance. The object of the Commission is the conservation of the natural resources of the country, and among matters to which attention is drawn are the reclamation of great areas of swamp; the acquisition on the part of the State of the deforested areas around the head-waters of streams that afford the chief water-supplies; the preservation of special areas of picturesque scenery; and the prevention of waste in the development of the mineral resources. Professor H. Conwentz (as noted in the Geological Magazine for September, 1909, p. 429) has urged the desirability of taking more care of natural objects of interest, and our Coal Commissions have warned us not to be negligent of our limited supplies of coal. Maryland now supplies an example of organized effort to deal generally and practically with natural phenomena and resources.

3. Geology of the Country around Sheffield.—A very useful sketch of the geology, by Messrs. B. Hobson, Cosmo Johns, and C. Bradshaw, was issued in the Handbook and Guide for the British Association at the recent Sheffield meeting. Special attention is given to the fossils of the Carboniferous rocks and the Pleistocene mammalia, and there is a good colour-printed geological map.

4. Cornish Palæozoic Fossils.—Mr. J. H. Collins has prepared Addenda to the working list of Cornish fossils (Trans. Roy. Geol. Soc. Cornwall, xiii, pp. 385–427, 1910), his previous list having been drawn up eighteen years ago.

5. Rhodesia Museum, Bulawayo.—The eighth annual report of the Museum for 1909 contains an account of the gold-bearing rocks and a list of the minerals of the country, drawn up by Mr. A. E. V. Zealley, who last year succeeded Mr. F. P. Mennell as Geologist and Curator.

6. Mineral Production of India.—Vol. xxxix of the Records of the Geological Survey of India (1910) contains a Quinquennial Review of the Mineral Production during the years 1904 to 1908, by Sir Thomas H. Holland and Dr. L. Leigh Fermor. Comparing the average values

of the minerals produced during the period with that of the previous five years, an increase in value is noted in every case except rubies. The average increase, which amounts to more than 2¾ million pounds, is due mainly to progress in developing coal, petroleum, salt, gold, manganese-ore, and mica. Attention has been given also to the development of bauxite, copper-ore, and lead-silver ores.

7. Rivers.—In a paper brought before the Cotteswold Naturalists' Club, but regarded as too controversial for publication in the Proceedings, and now issued separately (Gloucester, 1910, price 1*s.*), Mr. T. S. Ellis has dealt with "The Winding Course of the River Wye". Believing that an area uplifted from the sea would have an irregular surface and that the streams would form a network, some meeting again after being diverted, some branching off to unite with other streams, he rejects the idea of primary consequent streams—we presume in the sense of their having an entirely independent origin. His observations lead him to conclude that the Upper Wye formerly continued its course through the Talgarth Valley to the Usk, and that tidal influence played an important part in forming the course of the river during the gradual elevation of the land.

8. River Action.—Mr. F. M. Burton, author of *The Shaping of Lindsey by the Trent* (1907), has issued another little work entitled *The Witham and the Ancaster 'Gap': a Study of River Action* (1910). In this the formation of the Ancaster Gap is attributed to a former course of the River Devon, which now flows into the Trent west of Newark. The possible influence of the ice of the Glacial Period in impounding the drainage and causing the erosion of the gap, as advocated by Mr. Harmer, is not discussed.

9. Geological Map of Cape Colony.—We have received two sheets of the colour-printed Geological Survey map on the scale of 3¾ miles to 1 inch, by Dr. A. W. Rogers and Mr. A. L. Du Toit. Sheet No. 40 includes the country around Marydale, traversed by the Orange River; and Sheet 32, which adjoins on the south, takes in the country around Van Wyk's Vlei. In the northern area the quartzites of the Kheis Series and large tracts of granite that intrude into them, dominate the country; in the southern area the Karroo System with dolerite intrusions extends over the greater part. Longitudinal geological sections are printed on the margins of the maps.

10. Geological Survey of Western Australia.—Bulletin No. 33 (1909) contains the results of "Geological Investigations in the Gascoyne, Ashburton, and West Pilbara Goldfields", by Mr. A. Gibb Maitland, Government Geologist, with Petrological Notes by Mr. J. Allan Thomson. It is well illustrated by 13 geological maps and 65 figures, comprising plans, sections, and pictorial views. The mineral resources, in addition to gold, include stream-tin, lead and copper ores, and mica. Artesian wells in the Gascoyne district yield more than eleven million gallons of water daily from seventeen bore-holes that range from 850 to 3,011 feet in depth. The rocks described by Mr. Thomson include schists, quartzites, cherty carbonates, marble, dolomites, serpentine, gabbro, amphibolite, dolerite, and granite.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

November 23, 1910.—Professor W. W. Watts, Sc.D., M.Sc., F.R.S., President, in the Chair.

The following communications were read:—

1. "The Effects of Secular Oscillation in Egypt during the Eocene and Cretaceous Periods." By William Fraser Hume, D.Sc., F.G.S., Director of the Geological Survey of Egypt.

The main points considered in the paper are:—

A (1). There is evidence of the gradual advance of the Cretaceous sea from north or north-east over Egypt during Upper Cretaceous times. Four stages in this advance are indicated by the geographical distribution of the Cretaceous deposits, and especially by the relations of the detrital Nubian Sandstone formation to the organic Cretaceous limestones. The four phases are: (*a*) A North Egyptian type, in which the Nubian Sandstone entirely underlies fossiliferous beds of Cenomanian (Lower Chalk) age. This extends across Egypt from Sinai to Baharia Oasis (*b*) A Wadi Qena type, developed near the head of the valley of that name, characterized by the alternation of Nubian Sandstone with fossiliferous Cretaceous beds. Three main divisions of Nubian Sandstone are recognized—one at the base of the Campanian (in the Upper Chalk), another above the Turonian (Middle Chalk), and a third below the Cenomanian beds, but closely related and passing into them. The recognition of the type was one of the most interesting results of this year's expedition in the Eastern Desert. (*c*) A Central Egyptian or Hammama type, in which the Nubian Sandstone forms the greater portion of the Cretaceous Series, only the Danian and Campanian beds being fossiliferous limestones or shales. This section is divisible into an Eastern facies, in which *Pecten* Marls are a special feature; and an Oasis facies, characterized by a fauna of small Gasteropoda, etc., in the shales, and species of *Echinocorys*, crinoids, and *Terebratulina gracilis*, etc., in a white chalk indicating a close affinity to the White Chalk of Northern Europe. These two divisions have been linked together by the discovery of the shales with the typical Oasis and small Gasteropod, etc., fauna in the same series as the *Pecten* Marls, and overlying them. The Campanian beds are characterized by the presence of phosphatic fish-beds. (*d*) A South Egyptian type has close resemblances to the Central Egyptian; but in the Campanian the phosphatic beds are inconspicuous, and a fauna of sea-urchins was discovered consisting mainly of new species.

The results of the Eastern Desert expedition of 1910 in Wadi Qena bear the strongest testimony to the Cretaceous age of the Nubian Sandstone.

B (2). As regards the transition from the Cretaceous to the Eocene, the following points are noted: The existence of two types of strata at the base of the Eocene: the first, the Luxor type, being fossiliferous, mainly characterized by the presence of *Operculina libyca*, etc., and largely developed in the Western Desert; the second, or Qena type, being on the other hand entirely unfossiliferous, and composed of

white limestones lithologically similar to the Danian white limestone below them, but structurally different. These beds, directly underlying fossiliferous Eocene strata, are honeycombed, closely jointed, and especially subject to erosion by water, the regularly bedded Cretaceous strata differing in these respects.

(3) A suggestion is made that these variations may be due to fold effects produced while the land was gaining on the sea at the beginning of Eocene times, the Qena limestones being remade Cretaceous material.

(4) Whereas in Southern Egypt Lower Eocene strata directly overlie the Danian strata, in Northern Egypt very marked unconformities exist between the Middle Eocene and the Cretaceous beds.

(5) The main palæontological differences between the Cretaceous and the Eocene are recorded, the principal feature being the sudden incoming of the large Foraminifera *Nummulites* and *Operculina*; in both formations oysters and sea-urchins are dominant, Brachiopoda being almost entirely absent.

C. In this section the distribution, zonation, and variation of the Eocene Series is considered, the main points being—

(6) The apparent uniformity of the fossiliferous Lower Eocene strata wherever developed.

(7) The lack of uniformity in the Middle Eocene strata, only the lowest zone, that of *Nummulites gizehensis*, being of wide distribution. The nature of the Eocene beds between Baharia Oasis and the depressions of Moela and the Fayum are described, zoned, and compared with the Middle Eocene in other parts of Egypt, the importance of the uppermost zone, the *Gisortia* Limestone, being emphasized.

(8) The influence of the gain of land over sea is traced through the Upper Moqattam Beds (with their increase in detrital materials and disappearance of *Nummulites*) and the Calcareous Grits overlying them to the quartz-chert gravels forming the desert west of Cairo and the Fayum, which are usually considered to be Oligocene, and mark the final stages in the growth of the Oligocene continent.

The Cretaceous Period in Egypt is, therefore, one marked by the gradual gain of sea over land; during the Eocene, on the contrary, land appears to have been steadily gaining on the sea, probably accompanied by gentle fold movements which account for the minor differences in the nature of the Eocene deposits. At the close of Eocene times and during the Oligocene Epoch the approach of a continental phase is clearly indicated, all the stages in these varied movements being illustrated in the desert regions.

2. "The Origin of the British Trias." By A. R. Horwood. (Communicated by Professor T. G. Bonney, Sc.D., F.R.S., F.G.S.)

It is maintained that, though desert conditions prevailed locally during the Triassic Period in Britain, deposition was brought about solely by the action of water; and the British Trias is a delta-system. For, during Carboniferous, Permian, and Triassic times deposition was mainly in the same area. There is, moreover, a gradual gradation from the Bunter to the Rhætic, from coarse sediments to fine. The Bunter is known to be of fluviatile origin, since Professor Bonney first

showed it to be so; and there is a continuity from Lower to Upper Trias, with an unconformity due to the new mode of formation and change in sedimentation. Oscillation and overlapping, which occur in the Trias, are admittedly due to aqueous agency. The Triassic outcrop and the delta area of the River Mississippi are closely similar. The alternations of pebbles and sands, sandstone and marl, etc., are due to those seasonal changes which are characteristic of deltas. Coloration is original, from below upwards, and not coincident with bedding. The thickness of the Bunter is an argument for a subsiding area. The ferruginous types in the Carboniferous, Permian, and Trias are alike due to delta conditions. The Trias is horizontal now, as originally, away from any ancient hills which it covers, and 'radial dip' is merely 'angle of rest'. It is only the skerries, furthermore, that are rippled. Screes, too, occur mainly to the south-west of submerged hills. Sandstones thin out eastward, marls westward, and the skerries are on the hills. The surface features of ancient hills once covered by Trias are quite unaffected; and desert conditions are merely marginal, limited to granitic or syenitic knolls at one horizon, while in the surrounding areas such conditions are absent. Rock-salt and gypsum are also horizontal and continuous in a linear direction. The Keuper gradually merges into the Rhætic phase, and the latter into the Lias. Since the Bunter sediments came from the north-west into the Midlands, so probably did the Upper Trias. Triassic sediments and those of the Nile are similar, but the first have been acted upon chemically, the latter mechanically. Local metamorphic and volcanic rocks may have provided some of the heavier minerals, but as a whole their source was more distant. The flora and fauna can be grouped in provinces around the delta-head of the Trias. These considerations all point to an aqueous mode of sedimentation in a moist and equable climate; and desert conditions only prevailed locally.

December 7, 1910.—Professor W. W. Watts, Sc.D., M.Sc., F.R.S., President, in the Chair.

Dr. A. S. Woodward communicated an account of recent excavations in the cavern of La Cotte, St. Brelade's Bay (Jersey), made during the present year by the Jersey Society of Antiquaries. According to the report of Mr. E. T. Nicolle and Mr. J. Sinel, shortly to be published by the Jersey Society, the cave has yielded evidence of human habitation and traces of Pleistocene Mammalia. About a hundred flint implements of the Mousterian type have been obtained, besides part of a molar of *Rhinoceros antiquitatis* and both teeth and antlers of *Rangifer tarandus*. Human remains and teeth of *Bos* have also been examined and determined by Dr. C. W. Andrews and Dr. A. S. Woodward, to whom the whole of the collection of mammalian remains was referred. This being the first discovery of typical Pleistocene Mammalia in the Channel Islands, the Jersey Society hopes to proceed with the excavations as soon as possible.

Dr. A. Strahan, F.R.S., Treas.G.S., delivered a lecture, illustrated by lantern-slides, on the occurrence of recent shelly Boulder-clay and other glacial phenomena in Spitzbergen.

II.—Mineralogical Society.

Anniversary Meeting, *November* 15.—Professor W. J. Lewis, F.R.S., President, in the Chair.

J. H. Collins: Further Notes on Wood-tin. It is concluded that wood-tin, which always contains a good deal of iron oxide and is much more opaque and more soluble than ordinary cassiterite, is the chalcedonic form, the shot-tin having had a concretionary and the botryoidal form a stalagmitic origin.—J. M. Coon: On the Alteration of the Felspar of Granites to China-clay. The action has taken place from within the earth towards the surface below the underground water-level, the water outlets being generally indicated by schorl and quartz veins. The nature of the products of the alteration was discussed.—Professor W. J. Lewis: On Wiltshireite, a new mineral from the Binnenthal. The crystals were tin-white in colour, russet-brown when tarnished; small, but aggregated in parallel position; with monoclinic symmetry, $a : b : c = 1{\cdot}587 : 1 : 1{\cdot}070 : \beta = 100° 44'$. Paucity of material prevented a chemical analysis, but no doubt it is a lead sulpharsenite. Named after the late Rev. Professor T. Wiltshire. — Arthur Russell: On a new locality of Phenakite in Cornwall. A single specimen showing numerous colourless, prismatic crystals of phenakite was found by him at Wheal Gorland, Gwennap, Cornwall, this year. The specimen obtained from a lode at present worked for wolfram and traversing the granite close to its junction with the killas.

CORRESPONDENCE.

BRONTEUS HALLI.

Sir,—You may like to note that the type-specimen of *Bronteus Halli*, H. Woodward (Geol. Mag., Sept. 1910, p. 407), has just been presented by the Directors of the North Devon Athenæum to the Trustees of the British Museum. It is being placed on exhibition in the Geological Department, and is registered I. 13645. The cast, which came to this Museum as part of the Townshend M. Hall Collection in 1886, was a wax squeeze of the holotype, and has been registered I. 2184. Mr. Hall had, however, previously presented two plaster casts, one of the holotype, one of its counterpart which, as stated in the paper, appears to have disappeared from the J. E. Lee Collection. These casts have been registered respectively, I. 13646, I. 13647.

Now neither the original specimen, collected in 1875, nor any of these casts bears on its label any indication that the specimen came from the Lower Middle Devonian, as stated in the legend to Fig. 1 (Geol. Mag., Sept. 1910, p. 408). "Middle Devonian" no doubt it is, and "Lower Middle Devonian" it may be; but one would like to have the evidence for this definite statement.

F. A. Bather.

October 11, 1910.

YORKSHIRE GEOLOGISTS AND RECORDERS.

Sir,—Having a fair knowledge of the names of fossil invertebrata I thought I would have a try at the prize-competition suggested by "Recorder" in your October number (p. 479). Here is my 'spot':—

Psil-onotus.	*Cor*-	*Ast*-ieria.	*Echi*-oceras.
Cal-	*Agas*-sizia.	*Nicro*- . . .	*Der*-oceras.
Schlot-heimia.	*Arn*-ioceras.	*Ambly*-ceras.	*Polym*- . . .
Ver-	*Arie*-tites.	*Oxyn*-otus.	*Upt*- . . . .

I write away from books, but the names seem to be those of Ammonites, and one is tempted to complete the list by the simple addition of *oceras*; I fear, however, that even so I should not get a place.

As a worker and a recorder myself I have often wondered why some writers should so delight in enigmas; but if the Geological Magazine would start a problem-page for such during the winter months, it might secure fresh subscribers and the wits of the coming generation might be sharpened.

What?

BEMBRIDGE FOSSILS ON CREECHBARROW HILL, ISLE OF PURBECK.

Sir,—I have just lately received from Mr. Keeping a copy of his paper on the finding of "Bembridge Limestone Fossils on Creechbarrow Hill", and asking my opinion on his paper. I cannot entirely agree with his conclusions, for the following reasons:—

1. His section (Geol. Mag., October, 1910, p. 437) appears to be taken from Alum Bay, Isle of Wight, and it seems to me that there is not sufficient space between the Chalk and the top of Creechbarrow for the whole series of beds to fit in.

2. The sand and flints which he regards as "Pleistocene drifts" may be so, but they were seen by the late Mr. Hudleston and myself in a pit (opened under my superintendence) *passing under the limestone*, and referred to by him (see Geol. Mag., 1902, p. 248). This is a point I desire particularly to call attention to.

3. As regards the piece of limestone mentioned by Mr. Keeping as having been picked up by a workman from among the gravel "at a depth of about 13 feet", there is considerable room for doubt, bearing in mind the probability of the piece having rolled down into the pit accidentally. It certainly does not disprove Mr. Hudleston's section showing a layer of flints *beneath the limestone*. The subject is certainly of sufficient interest for some able geologist to take up and investigate independently. Even if the Creechbarrow Limestone fauna and the Bembridge may be identical, they are not necessarily upon the same horizon, and may have existed in Lower Bagshot times. Why not?

A. H. Bloomfield.

Rose Cottages, Grange Road,
Wareham.
October 25, 1910.

THE HIGH-LEVEL GLACIAL DRIFT AND THE LAND-ICE HYPOTHESIS.

SIR,—The prevailing conception with regard to the manner in which the famous high-level shelly gravels have been transported, according to the land-ice hypothesis, may be fairly indicated by the following quotations:—

"It is difficult to understand how the ice could climb out of such a basin as that of the Irish Sea, and ascend such steep slopes as those of the Welsh hills up to a height of at least 1,350 feet." (Sir Archibald Geikie, *Text-Book of Geology*, vol. ii, p. 1319.)

"Even if the thickness of the ice cap over the Dumfries and Kirkcudbright hills had been about 2,500 feet, that, with every allowance for viscosity, would hardly give us a head sufficient to force a layer of ice from the level of the sea bed to a height of nearly 1,400 feet above it, and at a distance of more than 100 miles." (Professor Bonney, Presidential Address to British Association, Sheffield Meeting, 1910.)

The advocates of the land-ice hypothesis apparently do not resent this rendering of their views. On the other hand, as far as one can judge from their utterances, they seem to regard it as the inevitable statement of their case.

Though in favour of the land-ice view, I find it impossible to believe that a thick ice-sheet can plough up beach material with its front, and climb or rather be pushed bodily up steep and lofty hill slopes to heights exceeding 1,000 feet. On a small scale, with comparatively thin masses of ice and low hummocks, this may be a feasible operation; but if not physically impossible, it is an improbability of a very high order with a thick sheet of ice, when heights of from 500 to 1,500 feet have to be scaled. But is such a view necessary?

Thrusting and shearing are well-recognized factors in ice movement. Contortions accompanied by upward overthrusts have been observed by Chamberlin in the Bowdoin Glacier of Greenland; and in a photographic illustration which he has given of these, some of the fracture-planes are seen to be very oblique ("Glacial Studies in Greenland": Journal of Geology, 1897, p. 235). In this upward overthrust action we have a rational explanation of the manner in which beach material may be raised by land-ice to fairly lofty altitudes.

The tendency of this upward thrust-action would be to translate the bottom ice with its infrozen ground moraine to higher and higher levels as the ice moved onwards; and this tendency would become more marked where the ice-sheet encountered a hill, or had to force its way through a narrowing valley.

Is it not already admitted that the ground moraine can traverse an ice-sheet obliquely and finally reach the surface by this up-thrusting action in the ice; and why should not shells be permitted to reach the surface in this way? Is it not, moreover, by this means, rather than by a simple and bodily lifting of its sole, that a thick ice-sheet heaps itself to some extent against 'nunataks' which oppose its movement? Beyond such comparatively slight heaping of the ice, there appears to be no need to assume, on behalf of the land-ice